AN ANALYSIS OF AGRICULTURAL RESEARCH AND PRODUCTIVITY IN ALBERTA

Alberta
ENVIRONMENT COUNCIL OF ALBERTA

37V

An Analysis of Agricultural Research and Productivity in Alberta

January 1983

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PREFACE

In recent years, the Environment Council has become aware of a number of concerns about the long-term security of the agricultural land base. An in-depth look at the present status of the agricultural land base and at impacts that may affect the land base in the future seemed warranted. Accordingly, the Environment Council is investigating this important topic.

Since settlement of this province began, farming and ranching have been important aspects of life in Alberta. Agricultural land dominates the landscape in central and southern Alberta, as rich farmlands stretch to the horizon. Throughout the years, breaking of new farmland has continued at the fringes of settled areas, and land has been improved for agricultural use. The land base used for agriculture has increased, as have yields and production of crops. Agriculture has become an integral part of the social and economic fabric of Alberta.

In recent years, however, some concerns have been raised about the long-term security of the agricultural land base in Alberta. As the province grows, more land is needed for housing, transportation and recreation. The amount of new land available for agriculture is limited. Resource extraction is expanding rapidly. Some farming practices, such as summerfallowing, may be affecting soil fertility or land productivity. The acreage of land affected by salinization is increasing. Other activities, within or outside farming, are also having an impact on agriculture. The effects of each may be small, but evidence has been mounting that the cumulative effects may threaten the security of the agricultural land base itself.

In general, there appear to be three types of concerns:

1) loss and fragmentation of agricultural land
2) impacts on the capability of the land to produce agricultural products
3) impacts of other activities that influence the effectiveness and efficiency of agricultural activities.

The effects on agriculture can be direct, as in the loss of land, or indirect, as in the loss of service industries in a rural area. Some of these threats come from outside the agricultural industry, while others arise from agricultural activities and practices themselves.

The Environment Council investigation will examine the types and magnitude of perceived threats to the security of the agricultural land base and will speculate on some implications for the future. Problems for agriculture will be identified and discussed in light of what is being done about them now and what could be done about them in the future.

A series of reports has been prepared for this investigation. Some of them present background information which sets the stage for further examination of the subject. Other reports look at the three types of concerns outlined earlier. These reports are intended to provide information to stimulate public discussion about the security of the agricultural land base. It is anticipated that public hearings on this topic will provide an opportunity for Albertans to air their concerns, confidence, pessimism, or optimism about agriculture in Alberta.

This report, prepared for the Environment Council by Marv Anderson and Associates, analyzes in detail the present and future states of agricultural research in Alberta, with a view to assessing whether productivity can be increased.

The Environment Council acknowledges the important contribution this report makes to the investigation of the security of the agricultural land base. However, the views expressed are those of the author. The Council cannot accept responsibility for statements or opinions given herein, and does not guarantee the accuracy of statistics or quotations presented.

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SECTION I
INTRODUCTION

1.1 BACKGROUND

The Environment Council of Alberta is conducting a number of background studies which deal with the agricultural land base in Alberta. There is a growing concern that the agricultural land being lost to urbanization, salinity and erosion will seriously affect the future potential of Alberta's agricultural industry.

In September 1982, Marv Anderson and Associates Ltd. were retained by the Council to examine the opportunities for potential improvements in agricultural productivity arising from agricultural research. At present, there is considerable debate as to the ability of agricultural research to maintain an increasingly productive agriculture. Optimists would argue that new technologies will continue to increase production and productivity as has happened in the recent past. Others suggest that, perhaps, most of the "easy" gains have already been attained. Under this scenario, future technological breakthroughs would occur less frequently and be more costly to achieve.

This study attempts to assess the likely role of agricultural research in maintaining agricultural productivity in Alberta, based on an assessment of past and current agricultural research applications in Canada and abroad.

1.2 STUDY OBJECTIVES

The basic objectives of this study are to identify:

1. who (and where) is doing the agricultural research applicable to Alberta;
2. the focus of this research;
3. the factors which determine technology transfers to Alberta agriculture; and
4. the potential for productivity gains and production increases short-term (20 years) and long-term (50 years) for both crops and livestock in Alberta as a result of these applied technological changes.

Detailed terms-of-reference are appended (Appendix A).

Underlying the above is an implicit concern about maintaining the quality of existing agricultural lands and about land alienation. Can technological innovation offset current and future land losses or even serve to expand the effective agricultural land base?

1.3 METHODOLOGY

The work following relies on a combination of primary and secondary data. Published secondary information is used extensively in Sections II and III for the identification of where, how and when new technology is developed and adopted in Alberta. Secondary data is also utilized in Section IV to identify historical sources of growth in Alberta crop production and to develop accompanying productivity estimates for the province. Section V relies very heavily on survey information tabulated by Marv Anderson & Associates after personally interviewing numerous research personnel at most major research facilities on the Prairies.

1.4 STUDY OUTLINE

Consistent with the study objectives, the report is organized as follows:

SECTION II	TECHNOLOGICAL TRANSFERS TO ALBERTA AGRICULTURE
SECTION III	SOURCES OF GROWTH
SECTION IV	HISTORICAL PRODUCTIVITY CHANGES
SECTION V	THE ROLE OF ALBERTA - CANADA RESEARCH
SECTION VI	ALBERTA PROJECTIONS, 2000-2030
SECTION VII	SUMMARY

SECTION II

TECHNOLOGICAL TRANSFERS TO ALBERTA AGRICULTURE

2.1 INTRODUCTION

In this Section, two basic questions are addressed, namely:

(1) What is the source of the applied research used on Alberta farms? and

(2) What are the factors which determine when and how new technologies come into use?

These are discussed in turn in the sub-sections following.

2.2 SOURCES OF APPLIED AGRICULTURAL RESEARCH

Agricultural research is truly international in scope. Canada's share of world public expenditures on agricultural research is small, perhaps five percent of the total. The U.S. is the largest single performer of agricultural research, accounting for approximately 50 percent of the world research effort.

In Table 2.1, the relative importance of the research effort in Canada as compared to that of the U.S. and Western Europe is examined. The data emphasize the *relative* unimportance of the magnitude of research being undertaken in Canada, particularly at the private sector level. Of note is the difference in the private-public agricultural research mix between Canada and the U.S.

In general, the public sector is responsible for much of the biological research undertaken. Mechanical and chemical research tends to be conducted by the private sector. In these research areas, findings are often patentable allowing the innovating firm to capture the benefits of its research activities.

Much of the privately produced technology (machinery, agricultural chemicals, animal medicines, etc.) used on Alberta farms must be imported and adapted, where necessary, to meet the particular conditions of agriculture in Alberta.

Publicly funded research findings both in Alberta and elsewhere are diffused internationally via scientific journals, and national and international conferences of research scientists.

Table 2.1

ESTIMATED PUBLIC AND PRIVATE AGRICULTURAL RESEARCH EXPENDITURES, SELECTED REGIONS, 1980

Region	Private Expenditures		Public Expenditures	
	($M 1980)			
Canada[a]	52	(1.5)[b]	292	(8.5)
U.S.	2181	(63.4)	1327	(38.7)
Western Europe	1204[c]	(35.1)	1806	(52.8)
TOTAL	3437	(100.0)	3425	(100.0)

[a] Public research expenditures in Alberta amount to approximately 10 percent of the Canadian total. Private research expenditures are estimated to be less significant, perhaps 5 percent of total Canadian private agricultural research expenditures.

[b] Numbers in brackets indicate percentage breakdowns.

[c] Estimated at 40 percent of Western Europe total agricultural research expenditures.

Basic Sources: (1) Hamilton, D.G., **Evaluation of Research and Development in Agriculture and Food in Canada,** report prepared for CARC, January 1980.
(2) Dr. R. Evenson, Yale University, personal communication.
(3) Ruttan, V., **Agricultural Research Policy,** University of Minnesota Press, 1982.
(4) Dr. Y. Teklemariam, Alberta Agriculture, personal communication.

That Canada relies heavily on research undertaken in other countries is generally acknowledged.[1] Canada's dependence on foreign-produced technology in agriculture is merely an extension of our dependence on imported technology in the economy as a whole as indicated in Table 2.2.

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[1] Hamilton, D.G., **Evaluation of Research and Development in Agriculture and Food in Canada,** prepared for the Canadian Agricultural Research Council, Ottawa, January 1980, p.97.

Table 2.2
EXPORT/IMPORT RATIOS FOR SELECTED COMMODITY GROUPS, CANADA

Commodity Group	Period		
	1968-71	1972-75	1976-80
	(exports ÷ imports)		
Natural Resources and Raw Materials	4.5	4.4	3.7
Agricultural Products	1.3	1.5	1.3
Mineral Fuels	1.2	1.5	1.3
Manufactured Products			
- Resource-related Commodities	4.5	3.4	3.7
- Low Technology Commodities	.6	.6	.7
- High Technology Commodities	.5	.4	.4

Source: Statistics Canada, **Annual Review of Science Statistics, 1982**, Catalogue No. 13-212, Ottawa, annual.

From available data, the general message regarding new technology in Canada appears to be that ..."the greater the amount of technology required, the greater our relative dependence on goods produced abroad." [1]

In Table 2.3, provincial and federal agricultural research expenditures in Alberta over time and estimates of total federal expenditures in Canada are presented. Of particular interest is the recent growth in expenditures by Alberta Agriculture, due primarily to the introduction of the Farming for the Future program in 1977.[2] Funded by the Heritage Savings Trust Fund, the program makes funds

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[1] Statistics Canada, **Annual Review of Science Statistics 1982**, Catalogue No. 13-212, Ottawa, annual, p.60.

[2] The data in Column 4 indicate an annual growth rate of 8.5 percent for research spending in Alberta over the 1944-80 period (constant 1981 dollars).

Table 2.3

ESTIMATED TOTAL AGRICULTURAL RESEARCH EXPENDITURES, ALBERTA AND NATIONAL EXPENDITURES BY AGRICULTURE CANADA

Year	Alberta								
	Agriculture Canada [a] ($'000) (1)	Alberta Agriculture [b] ($'000) (2)	University of Alberta ($'000) (3)	TOTAL ALBERTA ($'000) (4)		TOTAL AGRICULTURE CANADA ($'000) (5)		Expenditures in Alberta as a percent of Total Agriculture Canada Expenditures [d] (6)	Research Expenditures Per Farm, Alberta [e] ($1981) (7)
1944	215	-	-	215	(1181) [c]	3863	(21225) [c]	5.6%	12.47
1945	207	-	-	207	(1125)	4396	(23841)	4.7	12.08
1946	350	-	-	350	(1842)	5375	(28289)	6.5	20.15
1947	460	-	-	460	(2212)	7098	(34125)	6.5	24.63
1948	547	-	-	547	(2298)	9338	(39235)	5.9	26.08
1949	747	-	-	747	(3049)	11751	(47963)	6.4	35.29
1950	1084	-	-	1084	(4302)	14094	(57527)	7.7	50.73
1951	998	-	-	998	(3590)	15081	(54248)	6.6	42.59
1952	1141	-	-	1141	(4004)	16266	(57074)	7.0	48.07
1953	1103	-	-	1103	(3898)	17390	(61449)	6.3	47.36
1954	1337	-	-	1337	(4708)	18778	(66120)	7.1	57.91
1955	1436	-	-	1436	(5039)	19858	(69677)	7.2	62.75
1956	1714	-	-	1714	(5931)	21484	(74339)	8.0	74.70
1957	1835	-	-	1835	(6158)	24136	(71933)	7.6	78.75
1958	2359	-	-	2359	(7709)	20544	(67137)	11.5	100.25
1959	532	-	-	532	(1716)	22407	(72281)	2.4	22.67
1960	2603	-	-	2603	(8290)	21885	(69697)	11.9	111.28
1961	2896	-	-	2896	(9165)	23082	(73044)	12.5	125.20
1962	2936	-	-	2936	(9175)	23672	(73975)	12.4	126.55
1963	2972	-	-	2972	(9117)	23758	(72877)	12.5	127.15
1964	3139	-	-	3139	(9455)	24983	(75250)	12.6	133.36
1965	3418	166	-	3584	(10541)	27612	(81212)	13.0	150.16
1966	3818	433	-	4251	(12077)	31200	(88636)	13.6	174.02
1967	4116	451	-	4567	(12512)	33801	(92605)	13.5	183.73
1968	4711	472	-	5183	(13639)	37732	(99295)	13.7	204.48
1969	4963	494	-	5457	(13746)	40129	(101081)	13.6	210.18
1970	5281	540	-	582[illegible]	(14198)	42863	(104544)	13.6	221.84
1971	5599	569	1002	717[illegible]	(16991)	45596	(108047)	15.7	270.99
1972	6390	601	796	7767	(17618)	52037	(117731)	15.0	282.34
1973	7181	636	1002	8819	(18527)	58478	(122853)	15.1	298.34
1974	8146	1936	1265	11347	(21491)	66337	(125638)	17.1	347.75
1975	9535	2194	1633	13362	(22841)	77649	(132733)	17.2	372.00
1976	10322	2419	1813	14554	(23175)	84059	(133852)	17.3	379.30
1977	11797	2533	1886	16216	(23882)	96067	(141483)	16.9	394.74
1978	13407	2734	1967	18108	(24503)	109178	(147737)	16.6	409.07
1979	14300	5076	2690	22066	(27343)	116450	(144300)	18.9	461.10
1980	15200	6310	2995	24505	(27565)	123779	(139234)	19.8	469.59

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[a] Based on operating costs of the Federal research facilities located in Alberta.

[b] Estimated operating expenditures. Includes expenditures under Alberta Agricultural Research Trust, Alberta Department of Agriculture Research Fund, Farming for the Future, Brooks Horticultural Research Center and the Crop Research Program.

[c] Numbers in brackets indicate expenditures in constant dollars. (1981=100).

[d] Column (4) + Column (5).

[e] Column (4) divided by estimated number of census farms. Basic source: Statistics Canada, *Census of Agriculture*, Ottawa, various years. Inter-census years have been interpolated.

Sources:
(1) Government of Canada, *Public Accounts*, Ottawa, various years.
(2) Expenditures by Alberta Agriculture provided by Dr. Y. Teklemariam, Alberta Agriculture.
(3) Expenditures by the University of Alberta obtained from; Office of Institutional Planning and Research, *Data Book*, University of Alberta, Edmonton, various years.

available to private industry and public research institutions. As yet, however, there has been no commitment to long-term continuation of the program.

Specific innovations important to Alberta's agricultural economy have originated from a variety of sources. Sources of improvement in crop varieties, beef cattle breeds, farm machinery and agricultural chemicals are discussed in the subsections which follow.

2.2.1 Sources of New Crop Varieties

The unique climatic conditions of Canada have made it necessary for Canada to engage in a strong national plant breeding program. Over time, research scientists have concentrated on developing varieties to meet the needs of the industry, either in terms of yield, time to maturity, drought and rust resistance, or other characteristics.

In Table 2.4, a listing of major varieties of selected crops and the licensing date, name and location of the breeder is presented. Of the thirty-six varieties listed, approximately eighty-six percent were developed at Canadian institutions. Seventeen percent of the total (six varieties) were developed in Alberta.

Development of the rapeseed (canola) industry is particularly illustrative: Despite the present importance of canola to Alberta's agriculture, only a small percentage of the research effort has actually been conducted in Alberta research facilities. As indicated in Table 2.5, rapeseed research in Alberta was negligible until 1969. The person-years expended in Alberta on rapeseed breeding have never exceeded 12 percent of the Canadian total.

These data strongly suggest that Alberta has been a net beneficiary of the canola research undertaken in this country. Canola's relative share of the value of Alberta's agricultural production likely exceeds its share of Alberta's agricultural research expenditures.

Table 2.4

LOCATION OF BREEDERS OF MAJOR CROP VARIETIES GROWN IN ALBERTA[a]

Crop/Variety	Date Licensed	Breeder
Wheat		
Marquis	—/—/10	Agriculture Canada Research Station, Ottawa
Thatcher	01/08/35	University of Minnesota, St. Paul, Minnesota
Rescue	12/04/46	Agriculture Canada Research Station, Swift Current
Saunders	19/03/47	Agriculture Canada Research Station, Ottawa
Chinook	28/05/52	Agriculture Canada Research Station, Swift Current
Selkirk	07/12/53	Agriculture Canada Research Station, Winnipeg
Canthatch	23/11/59	Agriculture Canada Research Station, Winnipeg
Park	05/03/63	Agriculture Canada Research Station, Lacombe
Manitou	22/02/65	Agriculture Canada Research Station, Winnipeg
Neepawa	24/03/69	Agriculture Canada Research Station, Winnipeg
Barley		
Newall	23/03/35	Agriculture Canada Research Station, Ottawa
Olli	31/01/36	Agriculture Canada Research Station, Ottawa
Montcalm	05/04/45	Macdonald College, McGill University, Montreal
Compana	28/04/49	Agriculture Canada Research Station, Ottawa
Gateway	11/03/53	University of Alberta, Edmonton
Parkland	01/03/56	Agriculture Canada Research Station, Brandon
Betzes	03/03/60	Krakow, Poland, Montana Agricultural Experiment Station, Idaho Agricultural Experiment Station
Conquest	22/02/65	Agriculture Canada Research Station, Brandon
Galt	16/02/66	Agriculture Canada Research Station, Lethbridge
Bonanza	08/01/70	Agriculture Canada Research Station, Brandon
Klondike	23/03/76	Agriculture Canada Research Station, Brandon
Klages	25/02/77	Dr. D. Wesenberg USDA, Aberdeen, Idaho
Flax		
Bison	09/10/30	Mr. H. Vaughan, Outram, Saskatchewan
Redwing	03/02/34	University of Alberta, Edmonton
Royal	16/02/39	University of Saskatchewan, Saskatoon
Dakota	16/04/47	Manitoba Seed Board, Winnipeg
Redwood	27/03/51	University of Minnesota Experiment Station, St. Paul
Raja	10/03/54	Agriculture Canada Research Station, Ottawa
Noralta	18/02/65	Agriculture Canada Research Station, Fort Vermilion
Rapeseed		
Arlo	14/05/58	Swedish Seed Association, Svalof, Sweden
Echo	08/04/64	Indian Head Experimental Farm, Indian Head
Span	03/03/71	Agriculture Canada Research Station, Saskatoon
Torch	06/02/73	Agriculture Canada Research Station, Saskatoon
Tower	22/02/74	University of Manitoba, Winnipeg
Candle	29/03/77	Agriculture Canada Research Station, Saskatoon
Altex	28/02/78	University of Alberta, Edmonton

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[a] Data provided courtesy of Grant Watson, Agriculture Canada, Ottawa

Table 2.5

PROFESSIONAL PERSON-YEARS DEVOTED TO RAPESEED BREEDING RESEARCH, 1960-61 to 1976-77[a]

Fiscal Year	Agriculture Canada Research Station Saskatoon[b]	University of Manitoba	University of Alberta	Total
		(Professional Person-years)		
1960-61	0.5	1.0	-	1.5
1961-62	0.5	1.0	-	1.5
1962-63	0.6	1.0	-	1.6
1963-64	0.7	1.0	-	1.7
1964-65	2.0	1.0	-	3.0
1965-66	3.5	1.0	-	4.5
1966-67	3.5	2.0	-	5.5
1967-68	3.8	2.0	-	5.8
1968-69	4.0	2.0	-	6.0
1969-70	6.0	1.5	1.0	8.5
1970-71	6.0	1.5	1.0	8.5
1971-72	6.0	1.5	1.0	8.5
1972-73	6.0	1.5	1.0	8.5
1973-74	6.0	1.5	1.0	8.5
1974-75	7.0	1.5	1.0	9.5
1975-76	7.0	1.5	1.0	9.5
1976-77	7.0	1.5	1.0	9.5

[a] Includes Professional Person-years for rapeseed breeding and Pathology in the areas of breeding for higher yields, lower erucic acid content and lower glucosinolate and fiber content.

[b] Includes Professional Person-years devoted to rapeseed breeding at Agriculture Canada Research Station, Indian Head, Saskatchewan.

Source: Dr. R.K. Downey, Agriculture Canada Research Station, Saskatoon.

2.2.2 Source of Genetic Improvement in the Beef Cattle Industry

Cattle are not indigenous to North America. British breeds have provided the basic genetic pool from which the Canadian beef industry has evolved. Until 1966, the industry was dominated by three breeds: Hereford, Aberdeen Angus, and Shorthorn. Lobbying by beef producers induced Agriculture Canada to open a quarantine station on Grosse Isle in the St. Lawrence in 1966. By 1976 the list of "most popular" breeds had expanded to twenty-six.[1]

The importance of European breeds ("exotics") provided the genetic diversity necessary to meet changing consumer tastes (less fat) as well as improvements in rates of gain, calf weaning weights and milk production over traditional breeds. The increase in the genetic pool resulting from the relaxation of import regulations has been a major factor in beef herd improvement in Alberta and the rest of Canada.

Improvement in beef production has not been limited to the importation of exotics. Developments in growth implants, artificial insemination, embryo transplants, disease control and rumen research have all contributed to an increasingly productive beef industry in Alberta.

2.2.3 Machinery

Improvements in farm machinery have tended to evolve slowly as a result of continuous small innovations rather than major changes. As detailed in the *Royal Commission on Farm*

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[1] Kerr, W.A., "The Supply of New Germ Plasm to the Canadian Beef Cattle Industry", **Technological Forecasting and Social Change,** Vol. 21, 1982, p.105.

Machinery,[1] many of the machines used today have evolved from implements first introduced in the 1800's. Some, such as ploughs and seed drills, have been in existence in crude forms for hundreds of years.

Unlike the crop sub-sector, which relies primarily on publicly financed research, agricultural machinery research is most often undertaken by private firms or individuals. The private sector is able to capture the benefits of research activity because innovations can be protected to some extent by patents.

Two important examples of mechanical innovations which have greatly increased producers' ability to perform work are the farm tractor and combine.

The tractor has evolved over the past century. Early forerunners of modern tractors were heavy, steam-powered machines used primarily for plowing. While an important technological advance, early tractors were slow and heavy and required large volumes of fuel.

The agricultural implement industry in Canada relied heavily on the American industry for providing the direction of technological advance. Tractor manufacturers in particular could not produce profitably in Canada. Some were forced to sell abroad; others arranged to sell the tractors of American firms in the Canadian market.[2] Only since WW II has tractor production in Canada been successful. Success has been dependent on access to the U.S. market by Canadian firms. At present, there are no tractor manufacturing companies in Alberta and only two (Versatile and Massey-Ferguson) Canadian-based firms producing farm tractors.

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[1] Vicas, A.G., "Research and Development in the Farm Machinery Industry", Study No.7, **Royal Commission on Farm Machinery,** C.L. Barber, Commissioner, Ottawa, 1970.

[2] Phillips, W.G., **The Agricultural Implement Industry in Canada, A Study of Competition,** University of Toronto Press, Toronto, 1956, p.37.

The combine was first proven successful in California. As early as the 1890's, companies were producing combines for this part of the U.S. on order. International Harvester was one of the first large-scale producers of combines in the U.S. and its Canadian subsidiary imported machines into Canada. Among Canadian firms, Massey-Harris (Ferguson) was, and remains, a leader in combine production. Again, Alberta farmers must rely to a great extent on access to technological innovations originating outside provincial boundaries.

Alberta-based manufacturers of agricultural implements are short-line companies concentrating on specific areas of agriculture such as grain drying, monitoring of agricultural implement performance (e.g. yield loss monitors) and tillage equipment.

In general then, farmers in Alberta import most of the mechanical technology now in use on Alberta farms. Alberta-based implement manufacturers do not provide full lines of agricultural machinery. Rather, implements produced tend to be job, and sometimes region, specific.

2.2.4 Agricultural Chemicals

As with farm machinery, agricultural chemicals are developed primarily by foreign or Canadian subsidiaries of large multi-national companies (e.g. Dow, Monsanto, Hoechst). High development costs make it necessary for these companies to manufacture chemicals which have large potential markets. While Canadians and Albertans in particular are spared the chemical development costs by taking advantage of foreign-produced technology, we probably incur some costs due to the time lag between chemical development and their eventual penetration into the Canadian market.[1]

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[1] Conversation with Dr. J. Dueck, Director, Agriculture Canada Research Station, Regina.

2.3 TRANSFER MECHANISMS

As much of the technology in use on Alberta farms comes from other countries or to a lesser extent other regions of this country, the transfer of new techniques is an important process. The transfer mechanisms which have evolved may take one of several forms.

One option is *direct transfer* whereby a province (or country) screens available technology and adopts innovations from other countries without altering them through research of its own. A second approach is *adaptive research* whereby borrowed technology is modified to meet local conditions.[1] Finally, a country can go it alone to produce its own unique technology from indigenous expertise. Canada and Alberta have relied extensively on the first two approaches.

The benefits of agricultural research often spill over across political boundaries. These externalities can be large (Table 2.6). Spillovers have been cited as one of the possible reasons why agricultural research is undervalued.[2] Provinces or countries can often receive the benefits of new technology without incurring development costs. The region undertaking the research bears the brunt of the cost but receives only a portion of the total benefits. For this reason, private firms tend to focus their research efforts on patentable types of innovations.

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[1] Evenson R.E., and H.P. Binswanger, "Technology Transfer and Research Resource Allocation", **Induced Innovation, Technology, Institutions and Development,** Johns Hopkins University Press, Baltimore and London, 1978, p.166.

[2] Evenson, R.E., Paul E. Waggoner and Vernon W. Ruttan, "Economic Benefits from Research: An Example from Agriculture," **Science,** Vol. 205, No. 4411, 1979.

Table 2.6

IMPACT OF INVESTMENT IN AGRICULTURAL RESEARCH AND EXTENSION, UNITED STATES

Subject	Maximum annual benefit from $1000 investment (dollars)	Annual rate of return (%)	Percentage of productivity change realized in the state undertaking the research
	1868 to 1926		
All agricultural research	12,500	65	Not estimated
	1927 to 1950		
Agricultural research[a]			
Technology-oriented	11,400	95	55
Science-oriented	53,000	110	33
	1948 to 1971		
Agricultural research			
Technology-oriented			
South	21,000	130	67
North	11,600	93	43
West	12,200	95	67
Science-oriented	4,500	45	32
Farm management and agricultural extension	2,173	110	100

[a] Technology-oriented research is defined as research where new technology is the primary objective. Science-oriented research has, as its primary objective, the answering of scientific questions related to the production of new technology.

Source: Evenson,R.E., **et. al.,** "Economic Benefits from Research: An Example from Agriculture," **Science,** Vol. 205, No. 4411, 1979.

Rates of return which might be expected from investments in agricultural research are presented in Table 2.7. While these studies generally ignore the social – environmental costs which might have been involved, the evidence suggests that returns are high; often much higher than the return to other research.[1]

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[1] Also see: Prentice, B.E., and G.L. Brinkman, **The Value of Agricultural Research in Ontario: Research Methodology, Data Sources, and Principal Findings,** OAC, University of Guelph, July 1982. In this recent study, the authors estimated the benefit-cost ratio of agricultural research in Ontario using a "value of inputs saved" approach. Their results indicate an overall benefit-cost ratio of 37.4 : 1.

Table 2.7

ESTIMATES OF THE RETURN FROM INVESTMENT IN AGRICULTURAL RESEARCH

Investigator	Year	Country	Commodity	Period	Annual Return (%)
Index number[a]					
Griliches	1958	United States	Hybrid corn	1940-1955	35-40
Griliches	1958	United States	Hybrid sorghum	1940-1957	20
Peterson	1967	United States	Poultry	1915-1960	21-25
Evanson	1969	South Africa	Sugarcane	1945-1962	40
Ardito and Barletta	1970	Mexico	Wheat	1943-1963	90
Ardito and Barletta	1970	Mexico	Maize	1943-1963	35
Ayer	1970	Brazil	Cotton	1924-1967	77
Schmitz and Schmitz	1970	United States	Tomato harvester with no compensation to displaced workers	1958-1969	37-46
			Assuming compensation of displaced workers for 50 percent of earnings loss		16-28
Scobie and Posada	1978	Colombia	Rice	1957-1964	79-96
Hines	1972	Peru	Maize	1954-1967	35-55
Hayami and Akino	1977	Japan	Rice	1915-1950	25-27
Hayami and Akino	1977	Japan	Rice	1930-1961	73-75
Hertford et. al.	1977	Colombia	Rice	1957-1972	60-82
		Colombia	Soybeans	1960-1971	79-96
		Colombia	Wheat	1953-1973	11-12
		Colombia	Cotton	1953-1972	None
Peterson and Fitzharris	1977	United States	Aggregate	1937-1942	50
				1947-1952	51
				1957-1962	49
				1957-1972	34
Winnergren and Whitaker	1977	Bolivia	Sheep	1966-1975	44
			Wheat	1966-1975	-48
Regression Analysis[b]					
Tang	1963	Japan	Aggregate	1880-1938	35
Griliches	1964	United States	Aggregate	1949-1959	35-40
Latimer	1964	United States	Aggregate	1949-1959	N.S.
Peterson	1967	United States	Poultry	1915-1960	21
Evenson	1968	United States	Aggregate	1949-1959	47
Evenson	1969	South Africa	Sugarcane	1945-1958	40
Ardito and Barletta	1970	Mexico	Crops	1943-1963	45-93
Evenson and Jha	1973	India	Aggregate	1953-1971	40
Kahlon et. al.	1977	India	Aggregate	1960-1961	63
Lu and Cline	1977	United States	Aggregate	1938-1948	30
				1949-1959	28
				1959-1969	26
				1969-1972	24
Bredahl and Peterson	1976	United States	Cash grains	1969	36
			Poultry	1969	37
			Dairy	1969	43
			Livestock	1969	47
Nagy and Furtan	1978	Canada	Rapeseed	1960-1975	95-110
Evenson and Flores	1978	Asia-national	Rice	1950-1965	32-39
Flores, Evenson and Hayami	1976	Philippines	Rice	1966-1975	27
Flores, Evenson and Hayami	1976	Tropics	Rice	1966-1975	46-71
Evenson and Flores	1978	Asia-national	Rice	1966-1975	73-78
Evenson and Flores	1978	Asia-international	Rice	1966-1975	74-102

[a] Index number estimates were computed directly from the cost of research on, say, hybrid corn, and the benefits were obtained from the estimated increase in production attributed to hybrid corn. Typically, the benefits and costs were assumed to continue indefinitely.

[b] Regression analysis estimates permit estimation of the returns from increased investment rather than the average return from all investment. The dependent variable is the change in total productivity, and benefit is defined as the value of the change in productivity. The independent variables include research variables, which reflect the cost of research and the lag between investment and benefit. The objective of the regression procedure is to estimate that component of the change in productivity that can be attributed to research.

Source: Evenson, R.E., *et. al.* "Economic Benefits from Research: An Example from Agriculture," *Science*, Vol. 205, September 1979.
Not significant, N.S.

Whether or not an innovation comes into use depends to a great extent upon the adequacy of information about the innovation available to the potential adopter. Lyster[1] examined the sources farmers used in obtaining that information about innovations and concluded that information on new crop varieties was obtained from the farm press (e.g. Country Guide, Grainews) far more than from any other single source (Figure 2.1). For specific crop varieties, the radio was also an important source of information, although much less so than farm papers. Local elevator agents and the farm press respectively were considered to be the most important source of information on new agricultural chemicals. The Figure further indicates the importance of market channels in the transfer of new knowledge. Universities and agricultural colleges also play an important role in the diffusion of knowledge. Students learn of innovations in farming and sources of information which can be applied when they return to the farm.

2.4 ADOPTION RATES

The rate at which producers adopt new technologies also influences overall productivity growth in agriculture. International evidence suggests that a considerable time lag can exist between introduction and adoption of innovations (Table 2.8).

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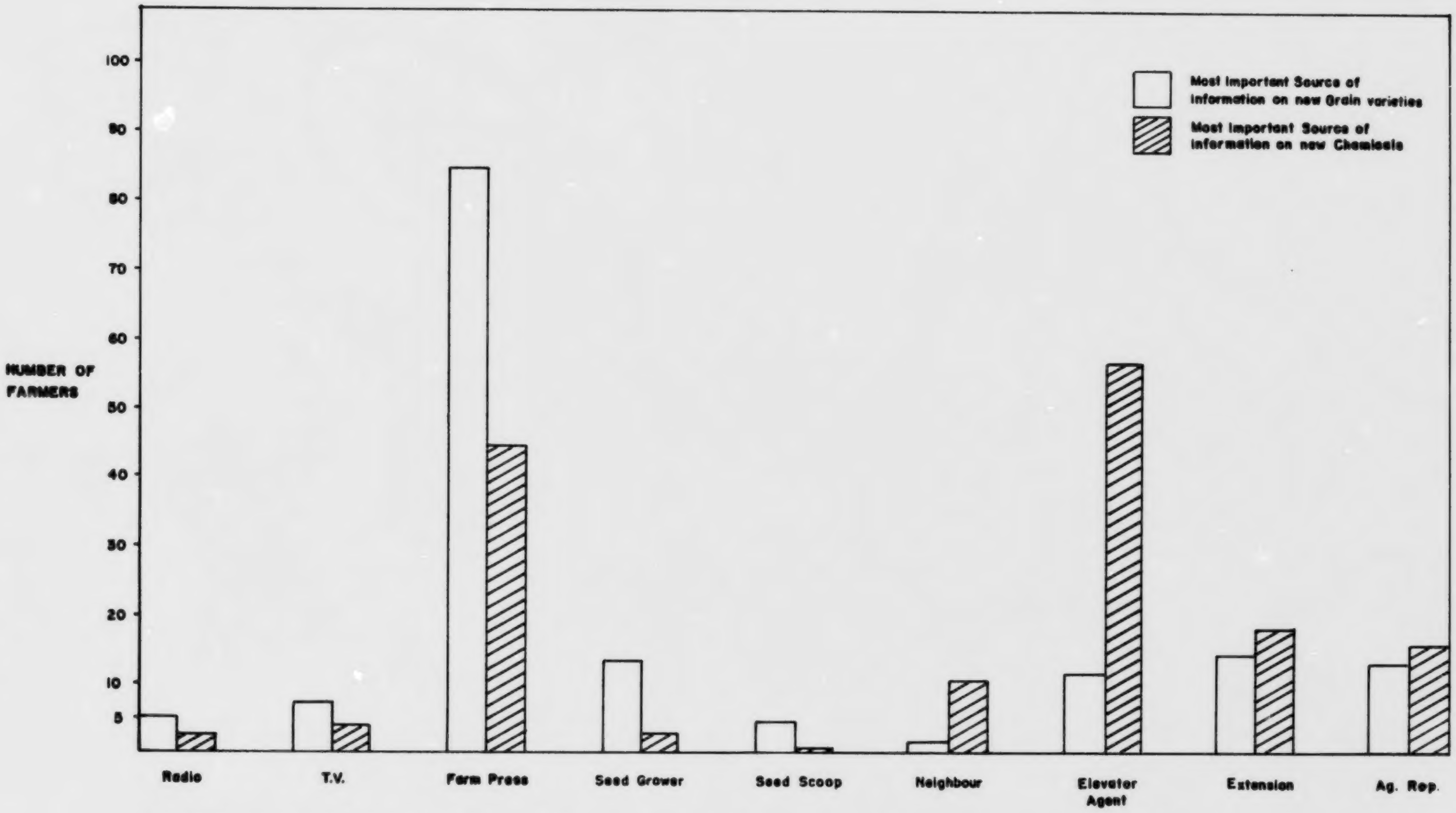
[1] Lyster, Bryan, "Information and the Farmer in Southern Saskatchewan," **Canadian Journal of Agricultural Economics**, Vol. 18, July 1970.

Figure 2·1

SOURCES OF INFORMATION ON NEW
AGRICULTURAL INNOVATIONS, SASK.



Basic Source: Lyster, Bryan, "Information and the Farmer in Southern Saskatchewan", Canadian Journal of Agricultural Economics, Vol.18, July 1970.

Table 2.8
TIME FOR ADOPTION OF NEW TECHNOLOGY
(95 Percent Acceptance)

Examples	Interval	Time (Years)
Vaccine for Marek's disease	1971-1973	2
Mechanical harvesting of grapes	1968-1971	3
High-yielding rice, Columbia	1967-1974	7
Hybrid corn, Iowa	1933-1940	7
Monogerm sugar beet seed	1956-1965	9
Mechanical harvesting of cherries	1961-1973	12
Hybrid sorghum	1955-1970	15
Hybrid corn, United States	1933-1969	36
High-yielding wheat, India (50 percent adoption)	1967-1973	6
High-yielding rice, Philippines (50 percent adoption)	1967-1973	6

Source: Wittwer, S.H., "Food Production: Technology and the Resource Base", **Science,** Vol. 188, No. 4188, May 1975.

A large number of studies have been devoted to the adoption process.[1] Sociologists have defined five stages in the adoption process. These include:[2]

(1) awareness
(2) interest
(3) evaluation
(4) trial
(5) adoption

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[1] See, for example: Griliches, Zvi, "Hybrid Corn: An Exploration in the Economics of Technological Change," **Econometrica,** Vol. 25, No. 4, October 1957, and M.M. Carillo-Huerta, "Determinants of the Adoption of Agricultural Innovations," **American Economist,** Vol. 21-22, 1977-1978, p. 50.

[2] Rogers, E.M., **Diffusion of Innovations,** The Free Press, New York, 1962.

In the awareness/interest stages the potential adoptor first learns of the innovation. At the evaluation stage more information is acquired to better understand the innovation and its potential. At the trial stage the innovation is adopted on a small scale. On the basis of the trial period, a decision is made whether or not to adopt the new technology for general use.

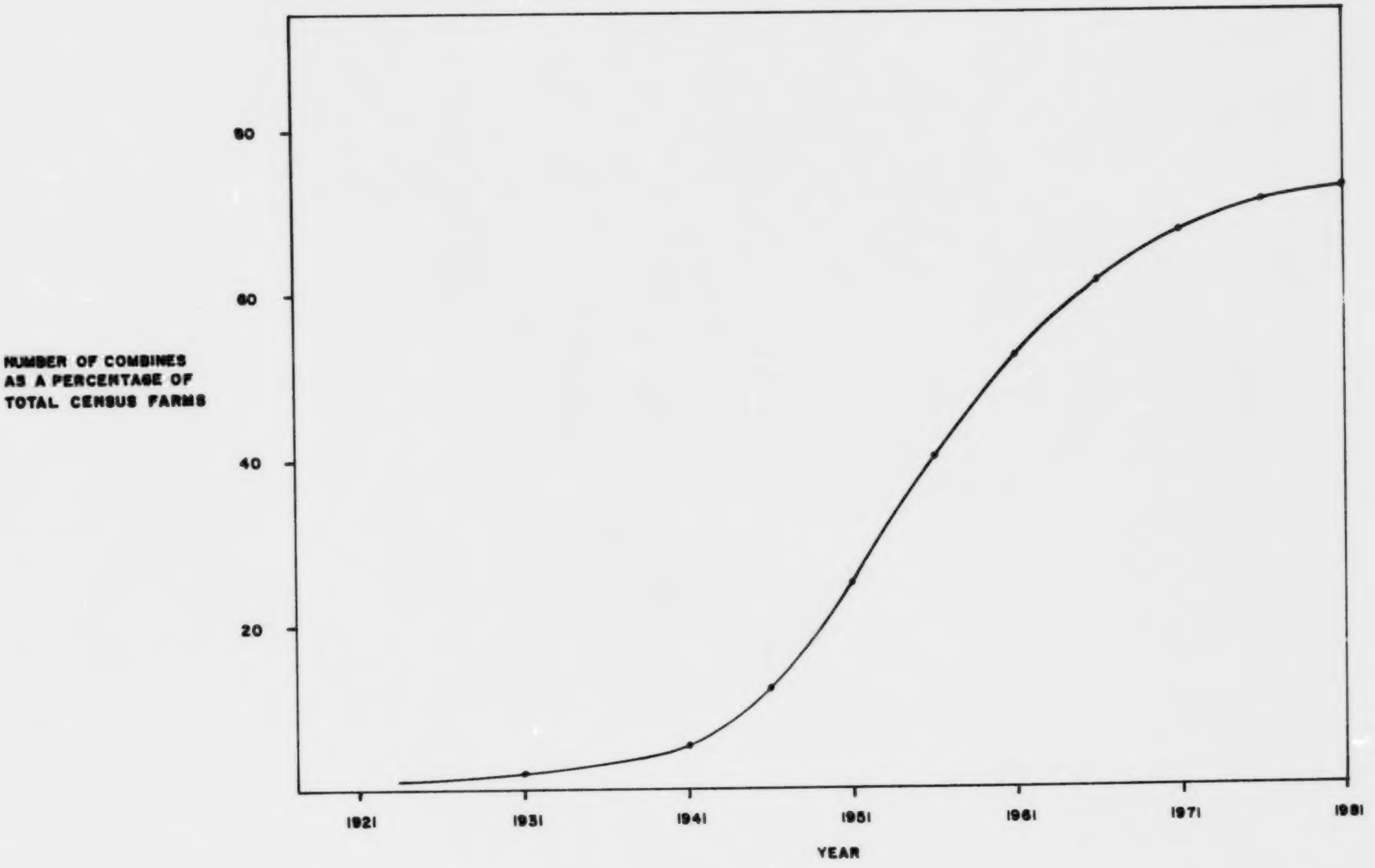
Adoptors are often categorized according to the rate at which they take advantage of available technology. Generally speaking, there are three broad classes: innovators, laggards, and the majority in between. The rate at which an individual decides to adopt will depend on numerous factors (Section 2.5).

When plotted against time, the percentage of a population adopting a given technology generally takes on an S-shape (Figure 2.2). The origin of the curve will depend upon the availability of the innovation. The rate of adoption (slope) and the ceiling will again depend upon a number of factors such as the relative profitability of the new technique in relation to existing techniques.

Figure 2·2

ADOPTION OF COMBINES ON ALBERTA FARMS

1921 - 1981



Adoption of Crop Varieties

In Figures 2.3, 2.4 and 2.5 following, the adoption of specific wheat, barley and canola varieties by Alberta producers is traced. Some varieties, such as Thatcher wheat, were adopted over a number of years and remained important for a long period of time. Other crop varieties such as Zephyr and Torch (canola) were adopted rapidly but became obsolete almost as quickly, to be replaced by improved varieties. Varieties such as Compana barley and Tower canola never accounted for a significant percent of total acreage but took a relatively long time to disappear from use.

Rapeseed/canola as a crop has been adopted very rapidly in Alberta. Seeded acreage in 1955/56 amounted to approximately 8,000 acres. By 1980/81, over 2,000,000 acres were devoted to canola production-- a 250-fold increase.

"Exotic Cattle"

In the case of beef cattle, until 1966, the strict quarantine regulations of the Canadian government severely hindered any significant genetic-based technological change in the beef cattle industry. Since the opening of quarantine stations in 1966, the main obstacle to rapid adoption has been the cost of importation--often as much as $2000 per animal *exclusive* of purchase price.[1]

Kerr has shown that despite the costs associated with importing beef cattle into Canada, market penetration has been relatively rapid.

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[1] Kerr, W.A., "The Supply of New Germ Plasm to the Canadian Beef Cattle Industry," **Technological Forecasting and Social Change,** Vol. 21, 1982, p.107.

Figure 2·3

ADOPTION OF NEW WHEAT VARIETIES
IN ALBERTA

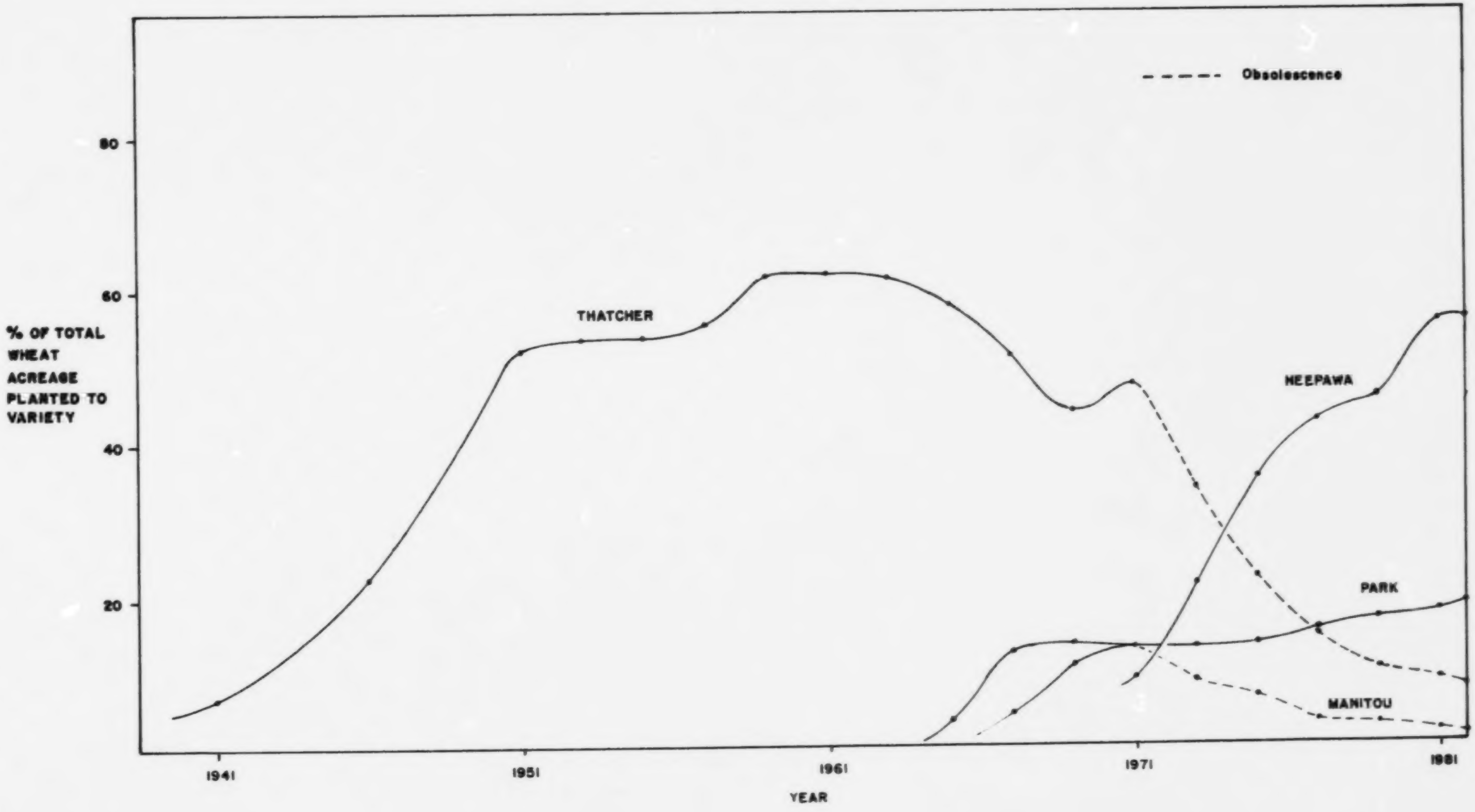


Figure 2-4

ADOPTION OF NEW BARLEY VARIETIES IN ALBERTA

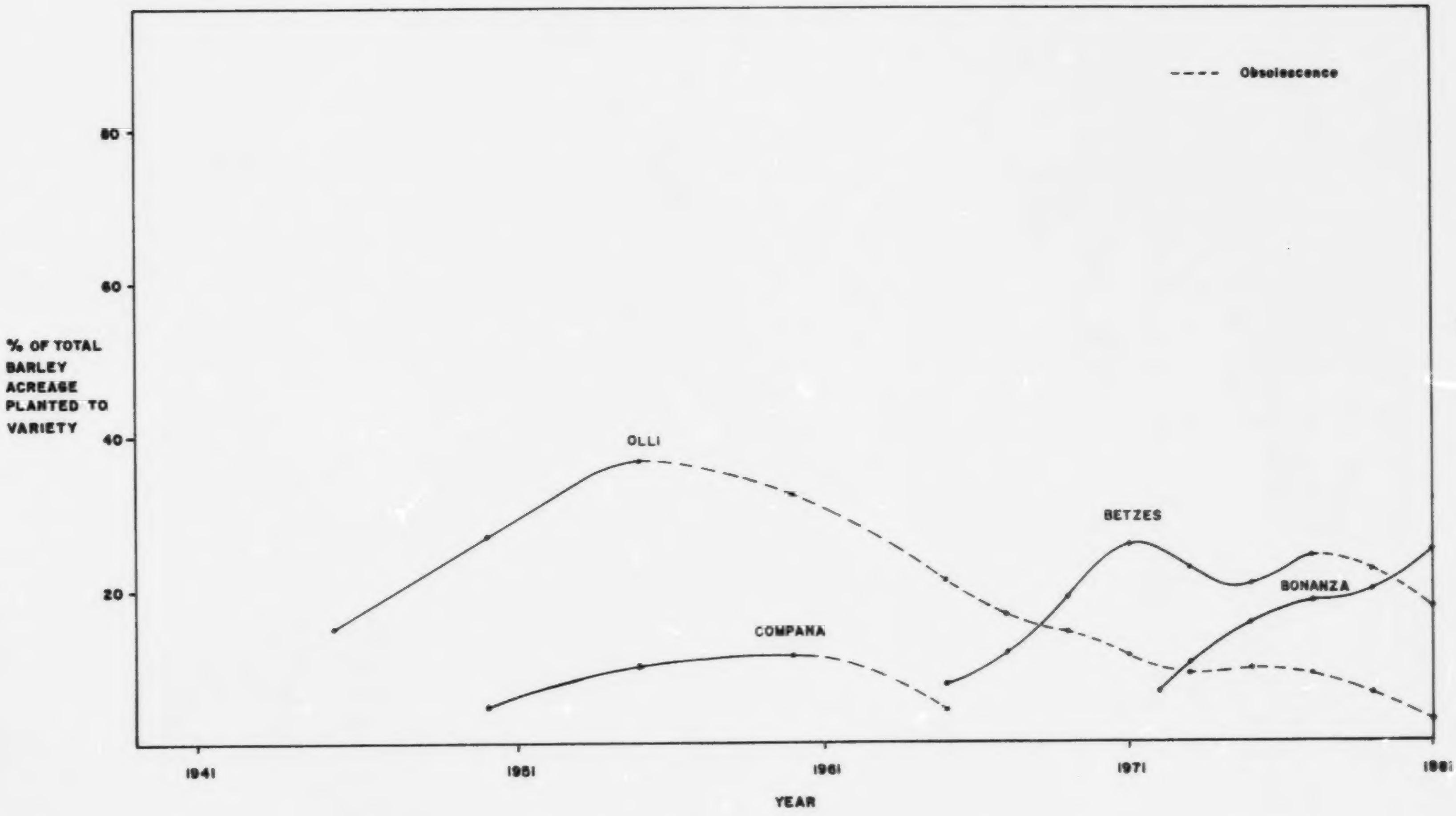
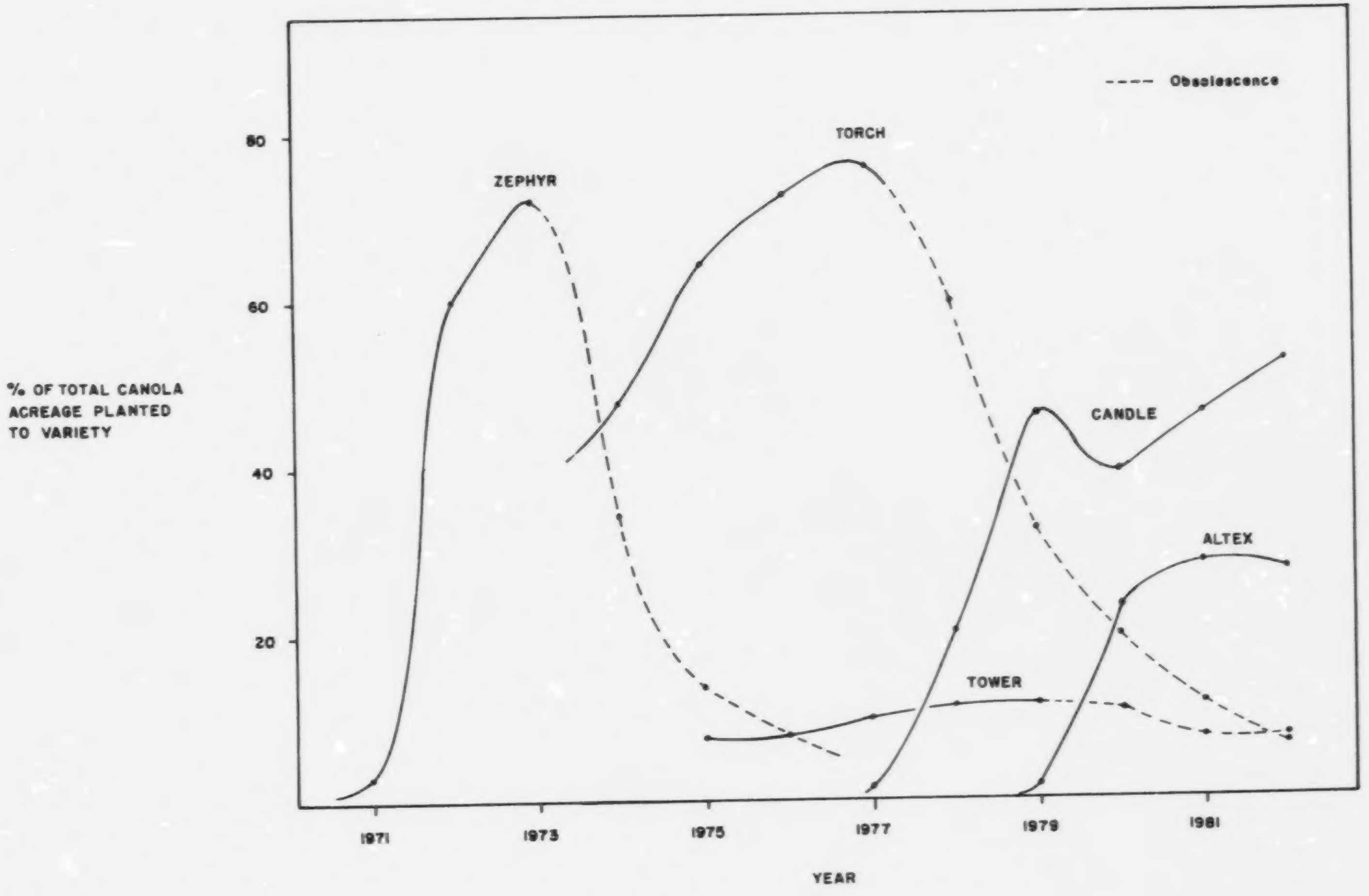


Figure 2-5

ADOPTION OF NEW CANOLA VARIETIES IN ALBERTA



The establishment of breeders was found to take place earliest in Alberta, followed by the rest of the Prairies, B.C., Ontario, Quebec and the Maritimes respectively. This reflects the size and relative importance of the beef industry in the various regions of the country. Market penetration for 18 "exotic" breeds for Alberta is provided in Table 2.9.

In the Table, the market was defined as the total number of cows in each census division and penetration of a market as the establishment of one breeder of a particular breed in that market.[1]

Agricultural Machinery

The adoption of agricultural implements has been a relatively slow process historically. The rate of adoption of farm tractors and combines is illustrative (Table 2.10). As indicated, it took approximately thirty years for the number of tractors on Alberta farms to approach an average of one per farm. About fifty years were required for the number of combines to reach about 70 percent of all census farms. Adoption of these machines was hindered by the fact that machines required a large cash outlay by farmers and represented an entirely new technology, not just an adaptation of existing technology.

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[1] Kerr, W.A., "The Supply of New Germ Plasm to the Canadian Beef Cattle Industry," **Technological Forecasting and Social Change**, Vol. 21, 1982, p.127.

Table 2.9

MARKET PENETRATION BY 18 EXOTIC BREEDS, ALBERTA 1978

Breed	Years until available to 90% of potential market	Years until available to 50% of potential market	% of market covered 1978
Charolais	5	1	99
Simmental	2	1	99
Limousin	7	2	92
Maine Anjou	5	3	99
Brown Swiss	5	2	99
Welsh Black	9	3	70
Murray Grey	4	3	99
South Devon	8	6	63
Chianina	3	3	99
Tarentaise	7	2	66
Blonde d'Aquitaine	3	2	92
Gelbveih	7	2	86
Salers	6	3	81
Normande	6	2	61
Pinzgauer	2	1	98
Romagnola	5	3	79
MRI	5	2	61
Marchigiana	2	1	94

Source: Kerr, W.A., " The Supply of New Germ Plasm to the Canadian Beef Cattle Industry", **Technological Forecasting and Social Change,** Vol. 21, 1982.

Table 2.10

NUMBER OF TRACTORS AND COMBINES ON CENSUS FARMS ALBERTA, 1921-1981

Year	Number of Census Farms	Number of Tractors	Number of Combines
1921	74,000	9,215 (12.4)	n.a.
1931	86,917	23,985 (27.6)	2,523 (2.9)
1941	93,200	36,445 (39.1)	5,165 (5.5)
1946	84,350	48,763 (57.8)	10,648 (12.6)
1951	84,315	79,282 (94.0)	20,851 (24.7)
1956	79,424	94,156 (118.5)	33,531 (42.2)
1961	73,212	102,624 (140.2)	38,530 (52.6)
1966	69,411	112,245 (161.7)	42,838 (61.8)
1971	62,702	111,256 (177.4)	42,373 (67.6)
1976	61,130	118,987 (194.6)	42,984 (70.3)
1981	58,056	124,214 (214.0)	42,663 (73.5)

[a] Numbers in brackets indicate numbers of tractors and combines as a percent of total census farms.

Chemical Fertilizer

The adoption of chemical fertilizers in Alberta is on-going. The trend, however, is clear. Since 1961, sales of fertilizer materials and mixed fertilizers in Alberta have increased nine-fold; from about 104,000 short tons to 945,000 short tons in 1981. On an improved acreage basis, this represents an increased usage of from about eight pounds per acre to over 60 pounds per acre (Figure 2.6).

Fertilizer presently accounts for more than ten percent of total farm operating expenses.[1] This could increase significantly as farmers adjust usage to recommended levels. Declining soil fertility may require greater fertilizer inputs to maintain crop yields.

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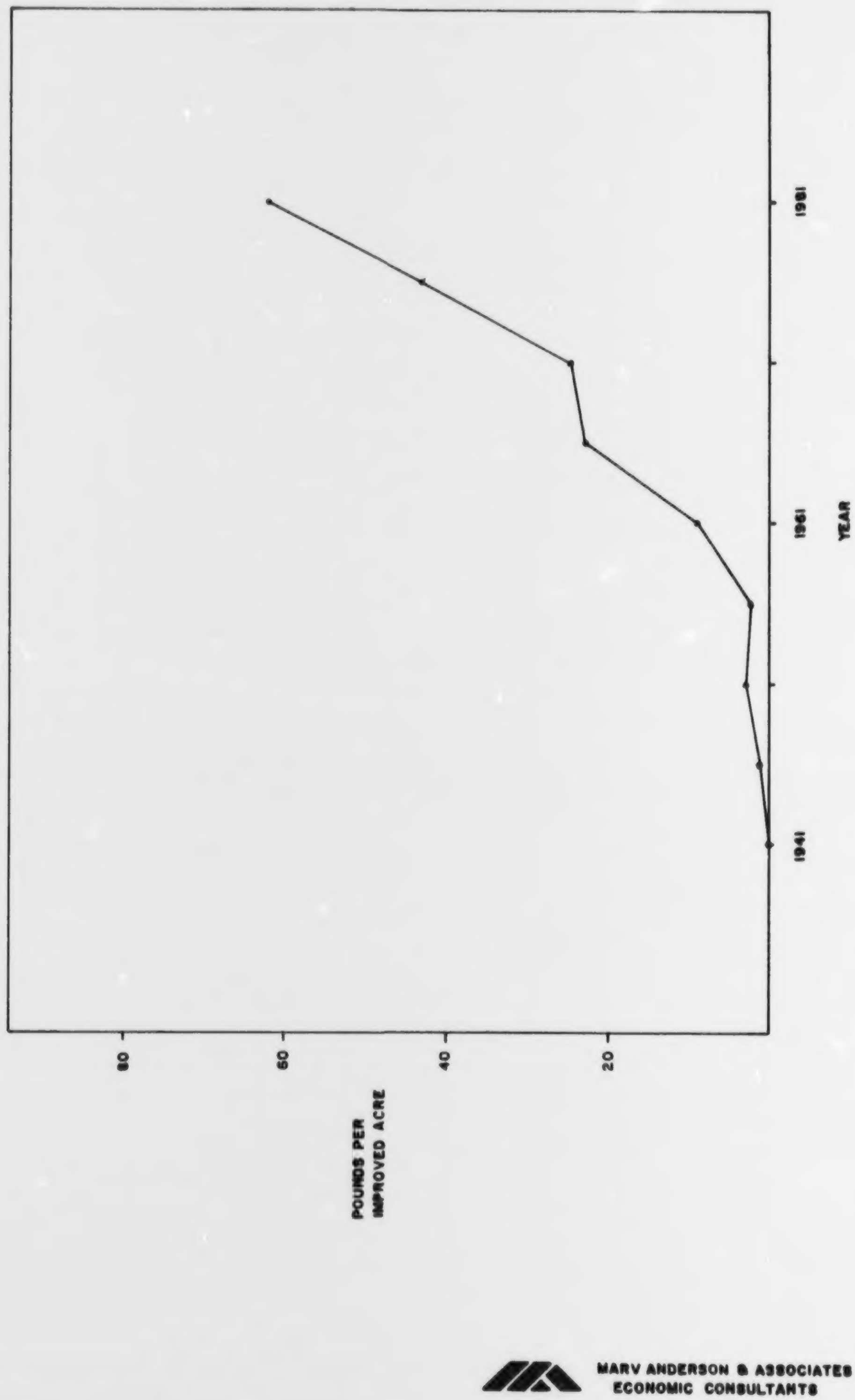
[1] Alberta Agriculture, **Agriculture Statistics Yearbook 1980**, Agdex 853-10, Edmonton, 1981.

Figure 2.6

ADOPTION OF CHEMICAL FERTILIZERS,
ALBERTA, 1941-1981



2.5 FACTORS AFFECTING ADOPTION RATES

The preceding Section has shown that on-farm adoption can and does happen fairly rapidly for specific innovations. However, it is clear that current technology is already far ahead of producers' acceptance of that technology as indicated by average and potential yields in Table 2.11.

Table 2.11

ACTUAL AND EXPERIMENTAL STATION YIELDS, SOUTHERN ALBERTA

(bushels/acre)

Crops	Actual Farm Yields	Experimental Station Yields[a]	Actual as a % of Experimental Yields
Spring Wheat	39	(65)	60
Soft Spring Wheat	51	91	56
Winter Wheat	51	(85)	60
Oats	70	117	60
Barley	73	128	57
Fall Rye	32	(53)	60
Flaxseed	20	(33)	61
Canola/Rapeseed	30	62	48
Alfalfa (tons)[b]	4.0	6.3	63
Corn, Silage (tons)[b]	4.6	6.3	74
Sugar Beets (tons)	17.0	25.9	65
Potatoes (tons)	12.8	21.9	58

[a] Estimates in brackets imputed.

[b] Dry matter, DM.

Basic Source: As calculated from numerous sources in: Marv Anderson & Associates Ltd., **Blood Indian Irrigation Feasibility Study: Agronomy Study Component,** Willingdon, Alberta, November, 1981, pp. 52-57 and Appendix B.

The Table underscores the non-physical considerations in the adoption decision. That is, it seems apparent that it is not always the potential contribution of a technology to increase output which is the deciding factor in the adoption process. What determines whether or not an innovation is adopted or remains "on the shelf" depends on a matrix of alternative decision variables.

Two obvious factors influencing adoption rates are perceived profitability and availability. A more comprehensive listing is presented below:

(1) Nature of the technical advance, i.e. output increasing or factor-saving (implications for relative factor returns).

(2) Appeal to farmer - satisfaction of perceived needs.

(3) Profitability.

(4) Compatibility with attitudes toward change.

(5) Simplicity/complexity of the advance.

(6) Availability - knowledge, materials and credit.

(7) Applicability - the advance facilitates immediate use and visible results or benefits more long run in nature.

(8) Cost - impose any explicit or hidden costs on those who adopt the change.

(9) Level of Risk - success in application assured.

(10) Education - knowledge and skill level of prospective users affect their desire to employ technological improvements.

(11) Communicability - results of employing the advance should be easily visible to all participants.

(12) Promotion - assistance, extension advice and advertising encourage trial of new knowledge or techniques.

(13) Current state of technology at the time the new technique is introduced.

(14) Relative factor prices of those resources currently employed in production activities at time of new technique introduction.

(15) Structure - contract farming for canners or processors (e.g. sugar beets).

The above underline the importance of social and economic influences in the adoption decision. The factors may act individually or in various combinations to affect adoption rates. The relevant or most predominant set of factors may vary nationally, regionally or between farmers as attitudes are influenced by debt loads, aversion to risk or education of the individual decision-maker.

SECTION III
SOURCES OF GROWTH

3.1 INTRODUCTION

There are three main categories of technological improvements which have accounted for much of the increase in production over time: biological, mechanical and chemical. The three categories are inter-dependent with output levels constrained by the most limiting of these growth sources. At any given time, the relative balance between these three sources will influence the level and growth of agricultural output. The following analysis is used to examine the role of these factors in the growth process.

3.2 BIOLOGICAL IMPROVEMENTS

3.2.1 Crop Production

While there is no question that crop production in Alberta has increased over time, it is useful to identify the major components of this increase.

From historical production, yield and price data the sources of growth of crop production in Alberta can be calculated using a methodology employed earlier by Patrick and Swanson. [1]

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[1] Patrick, G.F., and Earl R. Swanson, "Components of Growth in Grain Production in the North Central States: 1937 to 1977," **North Central Journal of Agricultural Economics,** Vol. 1, No. 2, July 1979.

For a given region or province the gross value of total grain production P_t, is defined as follows:

$$P_t = A_t \sum_i^6 W_i C_{it} Y_{it}$$

where	A_t	is the area of grain crops seeded in period t.
	C_{it}	is the fraction of the grain crop area devoted to the ith crop during period t
	W_i	is the price weight of the ith crop and
	Y_{it}	is the yield of the ith crop in period t.

The price weights, W_i, are long-run average prices ($1981) and remain constant for all periods. Thus, changes in production between periods will be net of price fluctuations. Six time periods (t) are considered: 1926-30, 1936-40, 1946-50, 1956-60, 1966-70, and 1976-80. The crops included in the index are wheat, oats, barley, rye, flax and rapeseed.[1]

Using this basic formulation, changes in grain production between any two periods can be decomposed into four components:

$$P_1 - P_0 = (A_1 - A_0) \sum_i^6 W_i C_{i0} Y_{i0} \qquad \text{(Term 1)}$$

$$+ A_1 \sum_i^6 W_i C_{i0} (Y_{i1} - Y_{i0}) \qquad \text{(Term 2)}$$

$$+ A_1 \sum_i^6 W_i Y_{i0} (C_{i1} - Y_{i0}) \qquad \text{(Term 3)}$$

$$+ A_1 \sum_i^6 W_i (Y_{i1} - Y_{i0}) (C_{i1} - C_{i0}) \qquad \text{(Term 4)}$$

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[1] Basic area, yield andprice data found in: Statistics Canada, **Handbook of Agricultural Statistics, Part I, Field Crops,** Catalogue No. 21 516, Ottawa, Occasional.

The first term on the right represents *the effect of a change in the area seeded,* assuming that the cropping pattern or crop mix and yield are held constant at the initial period levels. The second term represents *the effect of the yield component* of growth, assuming the crop mix had remained the same as in the initial period. The crop mix effect, the third term on the right, represents the *effect of changes in the fractions or proportions of the total area* in grain devoted to specific crops. A positive crop mix effect indicates that the cropping pattern has changed to crops with a high gross value per acre expanding relative to the other crops. The final term, the yield-crop mix interaction, indicates *the cropping pattern response to differential yield changes.* If the yield of one crop increased relative to all of the other crops, the area devoted to that crop could be expected to increase relative to the area devoted to others, resulting in a positive interaction component.

To facilitate comparisons between periods, individual effects are expressed as a percentage of the total change in production. For example, a yield effect of 75 percent indicates three-quarters of the increased production is due to higher yields, but it does not imply that yields have increased 75 percent.

A negative percentage value on any component indicates that if only that component had changed, then total output would have declined. Results for Alberta are presented in Table 3.1.

Table 3.1

COMPONENTS OF GRAIN PRODUCTION INCREASE, ALBERTA
1926/30 - 1976/80

Period	Area Effect	Yield Effect	Crop Mix	Crop Mix -Yield Interaction	TOTAL
1926/30 - 1936/40	-802.8	890.3	44.2	-31.7	100.0
1936/40 - 1946/50	76.5	105.6	-57.7	-24.4	100.0
1946/50 - 1956/60	-19.2	132.3	-9.0	-4.1	100.0
1956/60 - 1966/70	33.3	79.4	-8.8	-3.9	100.0
1966/70 - 1976/80	54.2	77.2	-32.5	1.1	100.0

As indicated, the area affect was strongly negative between 1926/30 - 1936/40. For other periods, the area component of grain production increase was positive or slightly negative. Yield effects have been positive over all periods, suggesting continued improvements in crop yield over time. Crop mix and crop mix-yield interaction effects have tended to be negative but generally of a much smaller magnitude than either the area or yield effects.

For the two most recent periods examined, the results indicate that higher yields are only a partial explanation of increases in crop production in Alberta. Increased areas under cultivation have also been a significant factor.

Average crop yields have increased steadily over time in Alberta (Table 3.2). These increases have been due to a number of factors: genetic improvements, better management and increased use of fertilizers and other capital inputs. Historical yield increases for wheat, oats and barley are illustrated in Figure 3.1.

Table 3.2
AVERAGE ANNUAL CROP YIELD INCREASE IN ALBERTA, VARIOUS YEARS
(percent)

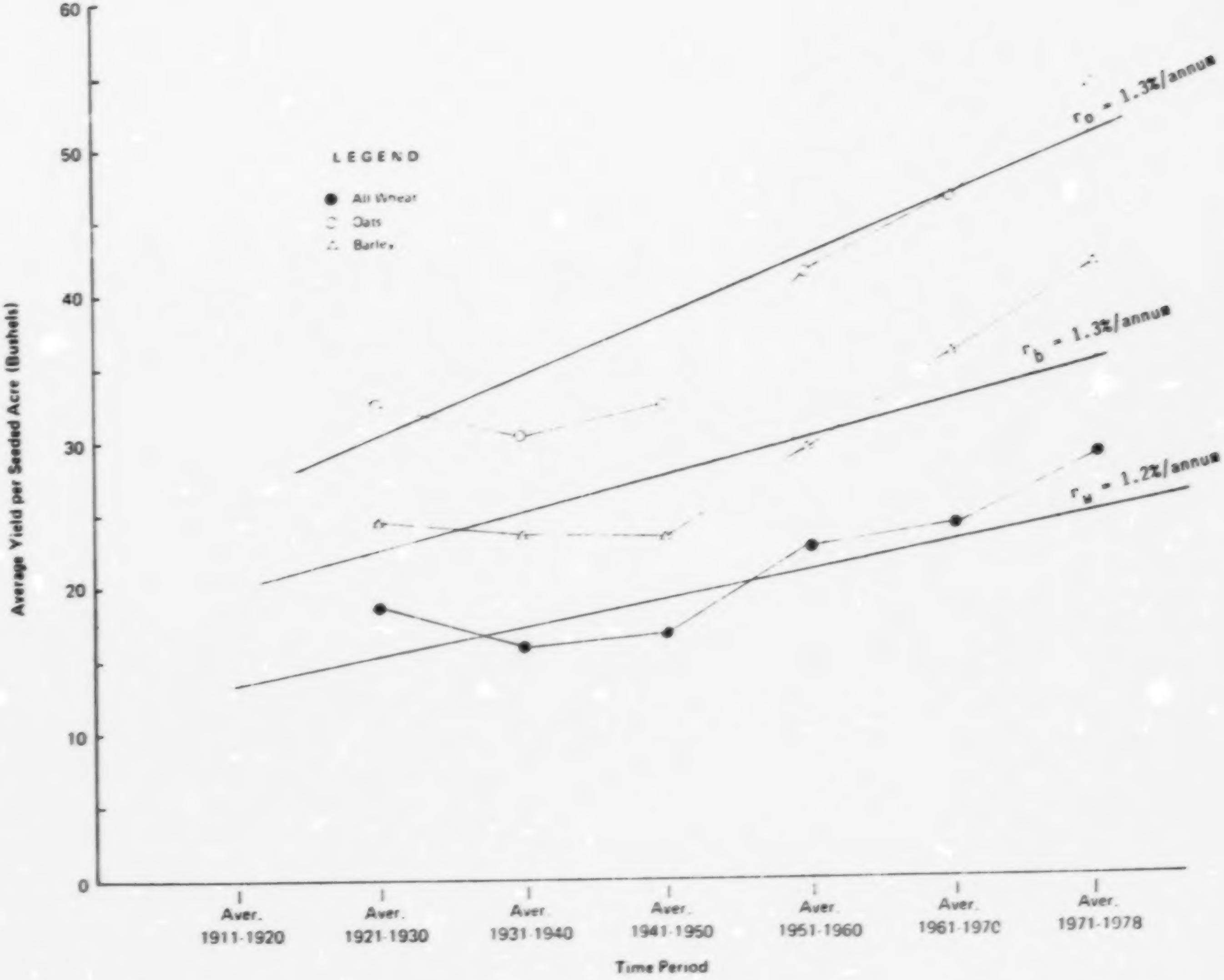
Crop	Period						
	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80	1921-80
Wheat	5.5	0.7	2.4	2.6	4.7	0.2	1.2
Oats	3.0	0.4	2.6	2.7	2.7	1.5	1.3
Barley	0.9	0.2	2.6	1.6	3.9	2.4	1.3
Rye	4.4	11.2	3.2	2.2	5.1	3.1	1.9
Flax	7.8	4.5	2.2	2.0	4.4	4.2	1.9
Canola	-	-	-	2.5	0.1	3.3	1.6

Basic Source: Statistics Canada, **Handbook of Agricultural Statistics, Part I, Field Crops,** Catalogue No. 21-516, Ottawa, Occasional.

To estimate the realized increases in yield over time due to genetic improvements, relative yield indices for the major varieties of wheat, barley and canola grown in Alberta were obtained. These were subsequently used to weight the share of cropped acreage devoted to that crop variety. Varieties accounting for less than two percent of cropped acreage or for which indices were unavailable were assumed to have an index value of 100. Growth in the weighted yield indices were then compared to indices of actual crop yields over a similar time period. Results are presented in Table 3.3 (Also see Appendix B, Figures B.1, B.2, and B.3). The divergence of the "actual" and "genetic" indices for all three crops suggests that many factors influence yield levels at the farm level in addition to improvements in physical yield capabilities. Particularly for wheat and canola,

Figure 3.1

AVERAGE YIELD PER SEEDED ACRE FOR WHEAT, OATS, AND BARLEY
FROM 1921- 1930 to 1971-1978.



Source; P.S. Thompson, **The Agricultural Land Base in Alberta,** ECA, Edmonton, 1981, p.46.

Table 3.3

REALIZED GENETIC INCREASES IN CROP YIELDS VERSUS ACTUAL YIELD INCREASES, ALBERTA

Year	Crop					
	Wheat Index		Barley Index		Canola Index	
	Actual	Genetic	Actual	Genetic	Actual	Genetic
1955	100.0	100.0	–	–	–	–
1956	113.7	100.0	–	–	–	–
1957	82.0	100.0	–	–	–	–
1958	87.5	100.2	–	–	–	–
1959	89.7	100.3	–	–	–	–
1960	85.0	100.4	–	–	–	–
1961	67.8	100.4	–	–	–	–
1962	82.8	100.4	–	–	–	–
1963	107.7	100.5	–	–	–	–
1964	95.7	100.7	–	–	–	–
1965	108.6	100.9	–	–	–	–
1966	126.2	101.1	–	–	–	–
1967	97.4	101.1	100.0	100.0	–	–
1968	110.3	101.2	118.9	100.4	100.0	100.0
1969	113.4	101.2	124.2	101.2	85.6	100.6
1970	118.9	101.6	130.4	102.5	105.4	100.1
1971	113.3	101.5	122.4	105.2	96.4	100.6
1972	117.6	101.5	137.3	105.4	110.8	101.6
1973	115.9	101.9	121.1	106.3	98.8	98.5
1974	104.3	101.8	114.6	106.4	97.0	101.5
1975	128.7	102.1	131.0	106.4	107.2	102.8
1976	139.5	102.1	141.0	106.7	118.0	103.3
1977	106.4	101.9	142.5	109.1	137.1	103.5
1978	127.9	101.9	140.1	108.3	125.7	101.5
1979	121.9	101.7	142.5	109.4	108.4	99.1
1980	142.5	102.1	157.4	112.6	135.9	101.8
1981	143.8	102.4	149.1	114.4	125.7	101.9

Sources: (1) Statistics Canada, **Handbook of Agricultural Statistics, Part I, Field Crops,** Catalogue 21-516, Ottawa, Occasional.

(2) Saskatchewan Agriculture, **Varieties of Grain Crops for Saskatchewan,** Plant Industry Branch, Regina, various years.

the development of higher yielding varieties appears to have had a relatively small role in overall realized yield increases over the period under consideration.

The efforts of crop breeders at Canadian research facilities has, however, been far more important than what Table 3.3 would suggest. For example, Klondike and Johnston barley, licensed in 1976 and 1980 respectively, have yield indices 29 percent and 38 percent higher than Conquest, licensed in 1965. And, of course, yield is only one of the many characteristics which breeders attempt to improve on . Yield indices for a number of important wheat, barley and canola varieties are appended (Appendix B).

3.2.2 Livestock

Beef

Improvements in beef production have resulted from improved management and the introduction of new beef varieties. Between 1930 and 1981 the average calving rate for all cattle increased from about .59 calves per cow to over .80 calves per cow.[1] Over the entire period this represented an annual average rate of increase of 0.9 percent (Table 3.4).

Table 3.4

AVERAGE ANNUAL INCREASE IN CALVING PERCENTAGES
ALBERTA, 1931-1981
(percent)

Period	Growth Rate
1930-39	-1.1
1940-49	1.2
1950-59	2.6
1960-69	-0.1
1970-81	.4
1930-81	.9

Source: Statistics Canada, **Handbook of Agricultural Statistics, Part VI, Livestock and Animal Products**, Catalogue No. 21 514, Ottawa, Occasional.

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[1] Estimate based on secondary data found in: Statistics Canada, **Handbook of Agricultural Statistics, Part VI, Livestock and Animal Products**, Catalogue No. 21 514, Ottawa, Occasional, and, Alberta Agriculture, **Agriculture Statistics Yearbook**, Edmonton, various years.

The crossing of traditional beef breeds with the so-called "exotic" breeds has been shown to improve birth and weaning weights (Table 3.5). If an exotic sire is used, however, a greater weight can come at the expense of greater calving difficulty.

Table 3.5

INCREASES IN BIRTH AND WEANING WEIGHTS RESULTING FROM THE USE OF "EXOTIC" SIRES

Breed		Calf Weight			
Sire	Dam	Birth (lbs)	Birth Weight Index	200-day (lbs)	Weaning Weight Index
Angus	Hereford	90.1		511	
Hereford	Angus	91.1		499	
	Average	90.6	(100.0)	505	(100.0)
Limousin	Hereford	94.2		519	
	Angus	89.4		510	
	Average	91.8	(101.3)	514	(101.8)
Simmental	Hereford	96.9		554	
	Angus	93.6		550	
	Average	95.3	(105.2)	552	(109.3)
Charolais	Hereford	96.7		536	
	Angus	96.3		536	
	Average	96.5	(106.5)	536	(106.1)
South Devon	Hereford	97.3		526	
	Angus	92.0		521	
	Average	94.7	(104.5)	523	(103.6)

Source: USDA, **Germ Plasm Evaluation Program Progress Report No. 8,** U.S. Meat Research Center, September 1980.

Dairy

Improvements in milk production per cow have been continuous over the 1930 to 1981 period in Alberta (Table 3.6). Growth can be explained by a number of factors. Genetic improvements have been important. Dairy producers rely almost exclusively on Holstein cattle in the provincial herd. In terms of milk volumes the Holstein is more productive than any other breed. Management improvements are also significant. Better and more closely monitored feeding, the use of artificial insemination in straight crossing (i.e. Holstein X Holstein), and better disease control have all contributed to higher yields per cow over time (Figure 3.2).

Table 3.6

AVERAGE ANNUAL INCREASES IN MILK PRODUCTION PER COW, ALBERTA, 1930-1981

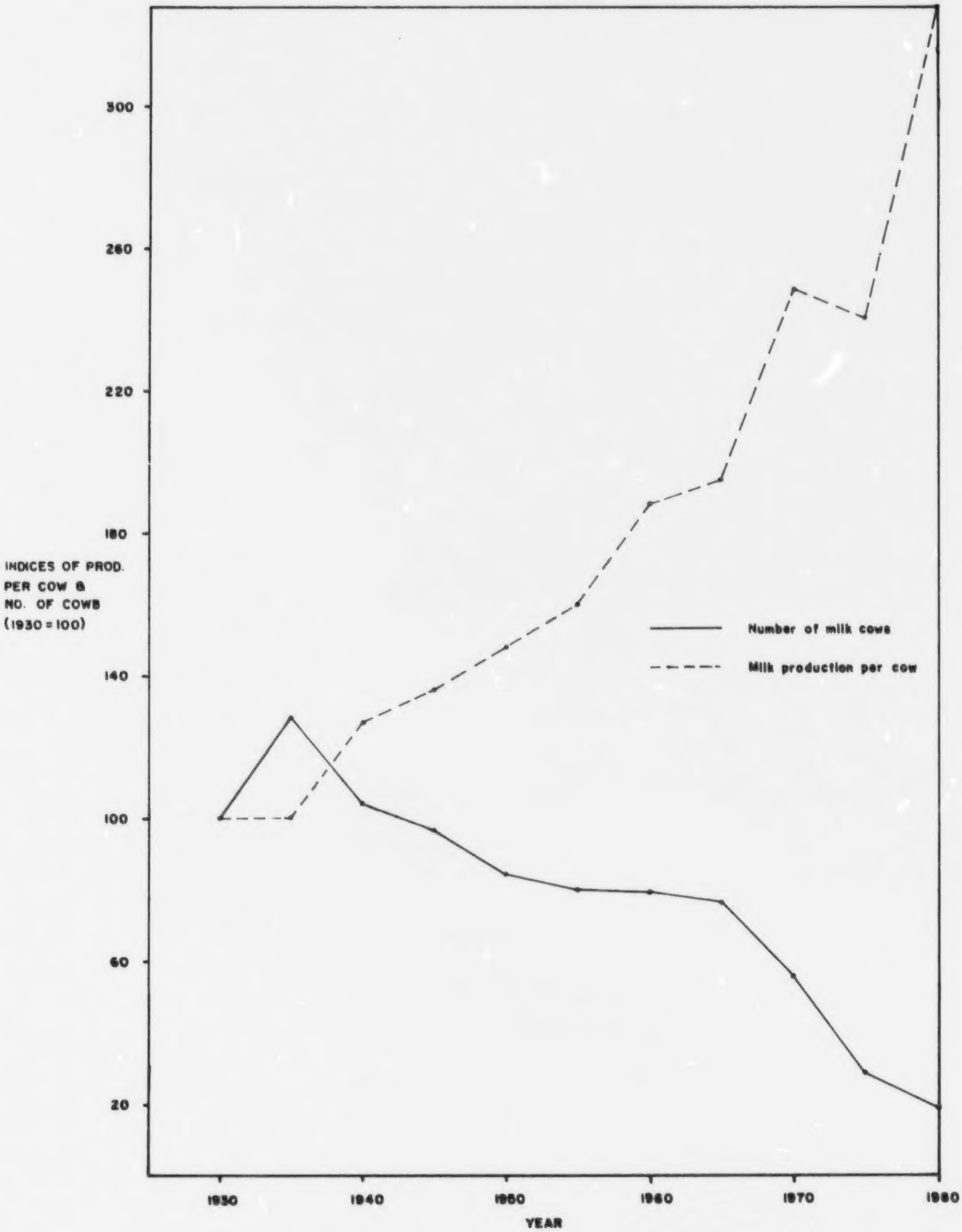
Period	Annual Growth (percent)
1930-39	2.7
1940-49	0.9
1950-59	2.7
1960-69	3.0
1970-81	2.5
1930-81	2.2

Source: Statistics Canada, **Handbook of Agricultural Statistics, Part VI, Livestock and Animal Products,** Catalogue No. 21 514, Ottawa, Occasional, and Alberta Agriculture, **Annual Report of the Dairy Division and Alberta Dairy Control Board,** 1981 82, Edmonton, 1982.

Figure 3-2

PRODUCTION PER COW VERSUS NUMBER OF COWS

ALBERTA, 1930-1980



Poultry

Improvements in efficiency in the poultry sector have, again, come as a result of better animal strains and better management. Birds have been bred for faster weight gains and greater egg production. Confinement, better feed rations and control of diseases (e.g. Marek's disease) have helped decrease mortality and increase feed conversion efficiency. Progress over the past forty years has been impressive (Table 3.7). Gains in production per bird should continue to be forthcoming at least over the next decade.[1]

3.3 MECHANICAL IMPROVEMENTS

Mechanization has had a major impact on agriculture throughout Canada. In response to changing relative factor prices, farmers attempted to maintain margins by shifting to relatively inexpensive, and more productive, inputs. This, in conjunction with the movement of labor off farms, and increasingly efficient farm machinery, tended to encourage growth in farm size and perpetuate farmers' reliance on purchased agricultural machinery. The structural changes which have occurred in Alberta's agricultural sector would not have been possible without advances in mechanical technology over time (Table 3.8).

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[1] Conversation with Dr. Robblee, Department of Animal Science, University of Alberta, Edmonton, November 22, 1982.

Table 3.7

EFFICIENCY OF POULTRY PRODUCTION IN ALBERTA , 1948 - 1982

Class of Bird	1948	1960	1975	1982
Broilers				
Market Weight	3.0 lbs	3.0 lbs	3.5 lbs	3.7 lbs
Age to Market	12.0 weeks	9.0 weeks	7.0 weeks	6.5 weeks
Feed/lb. gain	4.0-4.5(100.0)[a]	2.4-2.9(64.4)	2.0-2.5(55.5)	1.8-2.0(44.4)
Laying Hens				
Production/Year	170-180 (100.0)	240.0 (133.3)	260.0 (144.4)	270.0 (150.0)
Feed/Dozen eggs	5.5-6.0(100.0)	4.0-6.0(100.0)	3.8-4.2(70.0)	3.7-4.1(68.3)

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[a] Numbers in brackets represent partial productivity indices (1948=100)

Source: Dr. Robblee, Department of Animal Science, University of Alberta, Edmonton.

Table 3.8

STRUCTURAL CHANGES IN AGRICULTURE, ALBERTA, 1921-1981

Year	Number of Farms	Average Farm Size (ha.)	Number of People Living On Farms
1921	74,000	160	n.a.
1931	86,917	181	375,097
1941	93,200	188	383,964
1946	84,350	199	335,610
1951	84,315	213	345,222
1956	79,424	234	332,191
1961	73,212	261	287,814
1966	69,411	286	281,583
1971	62,702	320	237,924
1976	61,130	331	219,302
1981	58,056	329	190,755

Basic Source: Alberta Agriculture, **A Historical Series of Agricultural Statistics, for Alberta,** Agdex #850, Edmonton, 1969, and, Alberta Agriculture, **Agriculture Statistics Yearbook,** Edmonton, various years.

Greater use of, and improvements in farm machinery have greatly increased farmers' capacity to do work as reflected in agricultural labor productivity changes over time. Between 1946 and 1981, output per person-hour in Canadian agriculture increased 428 percent (from an index value of 24.6 in 1946 to 129.9 in 1981 (1971=100)).[1]

In Figure 3.3, the historical relationships between the value of farm output and the value of farm implements is illustrated. Increases in the value of output have closely tracked growth in the use of agricultural machinery.

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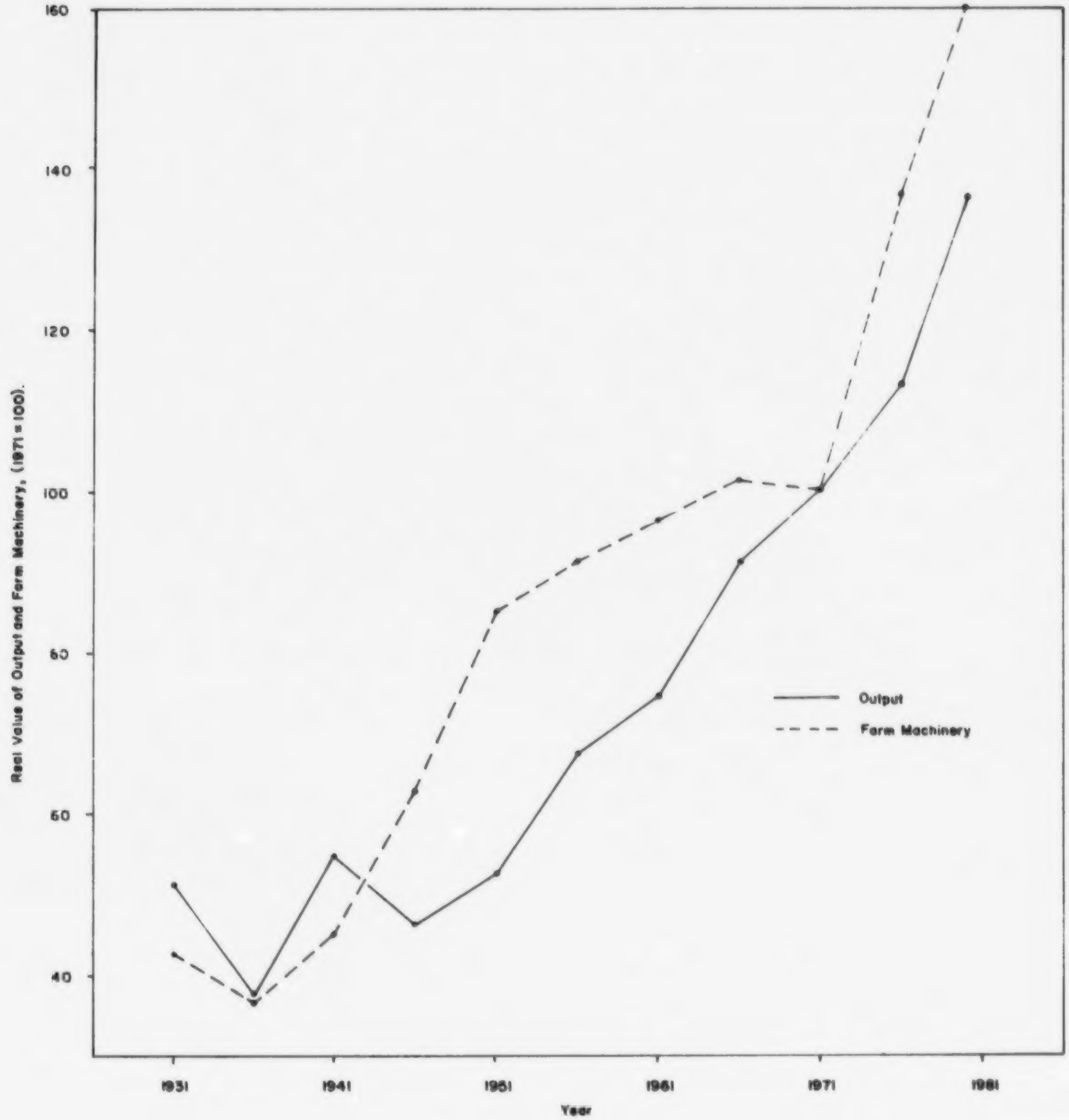
[1] Statistics Canada, **Aggregate Productivity Measures, 1981,** Catalogue No. 14-201, Ottawa, annual, p.31.

Figure 3·3

GROWTH IN FARM MACHINERY VERSUS FARM OUTPUT,
ALBERTA, 1931-1980



3.4 CHEMICAL IMPROVEMENTS

Use of agricultural chemicals on Alberta farms has complemented the genetic and mechanical improvements which have occurred over the last half-century.

Early weed control relied on adjustments in cultural practices. Summerfallowing, delayed seeding and post-seeding tillage were all practiced as weed management techniques with limited success. The introduction of swathers and combines aggravated the problem by increasing the numbers of weed seeds left on the ground.

The introduction of 2,4-D in the late 1940's was an important breakthrough. It provided excellent control of many broadleaved weeds at reasonable cost. Between 1948 and 1975, crop average treated increased from 1.1 million acres (445,000 ha.) to 6.2 million acres (2.5 million ha.), approximately 30 percent of the total area in field crops in Alberta.

In Table 3.9, the annual growth in the use of 2,4-D/MCPA and chemical fertilizers is presented. The relatively high rates of growth (particularly for fertilizers) further emphasize the importance of chemicals in modern agriculture.

Table 3.9

AVERAGE ANNUAL RATES OF GROWTH IN HERBICIDE (2,4-D/MCPA) AND FERTILIZER USE IN ALBERTA

Period	2,4-D/MCPA Growth Rate (%)	Fertilizer Growth Rate (%)
1940-49	-	24.9
1950-59	9.4	5.2
1960-69	-1.5	20.0
1970-75	4.7	18.9
1948-75	4.9	14.6

Basic Source: darWall Consultants, **Drought and Cultural Practices,** Saskatchewan Drought Studies, Element No. 8, Regina, 1982, pp. 274-275.

Because control of plant and animal pests is an on-going activity, new chemicals are being introduced every few years. Today, wild oats is considered to be one of the most serious weed problems facing western grain growers. Chemicals such as benzoylprop ethyl, flamprop methyl and diclofop methyl have recently been developed to deal with this weed problem.

That these wild oat chemicals are important in maintaining crop production levels can again be seen from the increase in treated area in Western Canada since 1967. From 520 thousand hectares treated in 1967, wild oat herbicides were applied to some 6.7 million hectares in 1978 -- a 13-fold increase.[1] Use in Alberta may account for one-third of the total.

3.5 SUMMARY

Historical increases in agricultural production in Alberta can be attributed to a number of different but complementary factors. Biological improvements in crop varieties and livestock breeds have increased the *potential* output per hectare or per pound of feed. More efficient machinery has made it possible for producers to perform necessary field operations at the correct time and to more exacting specifications. Fertilizers and other agricultural chemicals have cushioned the negative impacts of declining soil fertility, weeds, and plant and animal diseases. These factors, in conjunction with improvements in the management skills of producers, have made it possible for output levels to rise over time.

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[1] Hay, J.R., **Pesticides and Herbicides: Present and Anticipated Use by 1990**, Canada West Foundation, Calgary, 1980.

SECTION IV
HISTORICAL PRODUCTIVITY CHANGES

4.1 INTRODUCTION

Historical productivity measures in agriculture examine the relationship between total farm output and total farm input over time (in constant dollar terms). The level of output per unit of input (productivity) should not be confused with soil productivity -- the capacity of soil to produce crops expressed in terms of yield per unit area, or with production, which measures the gross output in physical terms (tonnes, bushels, etc.). Inputs typically considered are land, labor, machinery, fertilizer, agricultural chemicals and others utilized in the farm production process. It is when analysts begin to gather data for aggregation into appropriate variables which comprise the respective input and output indices that problems of productivity measurement occur. There are many ways to construct ratios of outputs to inputs, not all of which tell the same story. Alternative approaches to related methodological issues involving productivity measurement abound in economic literature.[1] Growth in agricultural productivity can be a result of improved efficiency in combinations of factors used in production or of gains in resource quality, or both.

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[1] For an intelligent and comprehensive discussion of relevant issues and alternative approaches to productivity measurement see, U.S. Department of Agriculture, **Measurement of U.S. Agricultural Productivity: A Review of Current Statistics and Proposals for Change,** Economics, Statistics and Cooperative Service, Technical Bulletin No. 1614, Washington, D.C., 1980.

4.2 PRODUCTIVITY MEASUREMENT

Alternative types of productivity index measures are possible because there are several different ways to measure outputs and inputs and to combine them into respective categories. There are two main types of commonly used productivity measures which differ in their handling of inputs -- partial productivity and total factor productivity. The ratio of output to quantity of a single input is called the *partial factor productivity* (PFP) of that input and the ratio of output to all inputs combined is called *total factor* or multifactor productivity (TFP).

Since partial productivity relates output to a single input, many measures of partial productivity can be constructed (e.g. land, machinery, labor, etc.). A commonly cited partial productivity measure is labor productivity since it is an important factor in agricultural production. Also, estimates of labor effort are often expressed in terms of "how many people a farmer can support" (e.g. as in, today a farmer produces enough food for 65 people).[1] Such measures are attractive in that they are easily calculated and understood. However, such an index also has its drawbacks since labor productivity does not account for contributions to production of the non-labor factors of production. This is especially significant for agriculture as other inputs are considerably more important in determining changes in the overall agricultural productivity index. Further, the PFP for labor does not account for the changes in amounts of non-labor resources employed in agriculture over time. Hence, labor productivity does not measure output obtained from given resources, nor does it measure the qualitative aspects of labor as a productive resource because increases in output per unit of labor may be obtained by increasing the use of machinery, fertilizer or other capital equipment. Other partial productivity measures such as yield per acre, pigs per litter or eggs per bird are often cited but remain subject to the same limitations noted for labor productivity.

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[1] U.S. Department of Agriculture, **op. cit.**, p.4.

Index Numbers

Due to the shortcomings in partial productivity measures, indices of total factor productivity are generally preferred as they permit the incorporation of methods to account for changes in the input mix or relative factor shares over time. This is not to say that the derivation of total factor productivity indices is without practical/methodological difficulties. A major problem inherent in the construction of TFP indices is the development of an aggregate input index. Dissimilar units of measurement for component factors of the aggregate input index such as hours of work, pounds of fertilizer or numbers of tractors tends to favour use of monetary values for these inputs as a common basis for aggregation. This necessitates weighting of the respective input components by their relative shares in the aggregate variable and no weighting system is faultless. For example, the index formula given below represents a Laspeyres weighted quantity index used to measure changes in productivity:

$$\frac{\Sigma \ Qn \ Po}{\Sigma \ Qo \ Po} \ (100)$$

The procedure uses prices recorded in the designated base year (Po) to weight quantities of component inputs to convert them to dollar measures in order to obtain an index value. Consider the use of this formula in the context of the following hypothetical example of multifactor productivity estimation for some farm commodity (e.g. hogs).[1]

Year	Output Index	Labor (hours)	Labor Wage	Non-labor Input Index	Price for Non-labor
1950	57	1161	$.60	60	$60.00
1975	98	249	$.60	110	$60.00

The total factor productivity index construction begins with the calculation of an index of total input. Price weights are used to convert labor and non-labor inputs to dollars, the dollar values are added together and a base year is designated (=100) to obtain an index. Choosing 1950 as the base year, the input index for 1950 and 1975 is calculated as follows:

Year	Labor	Non-labor		Input Index
1950	1161 X $.60	+ 60 X $60.00	= $4296.60	-----100 (base year)
1975	249 X $.60	+ 110 X $60.00	= 6749.00	--- $\frac{6749}{4296.60}$ X 100 = 157

---

[1] This example has been abstracted from two sources: Mason, R.D., **Statistical Techniques in Business and Economics,** Richard D. Irwin Inc., Homewood Illinois, Fourth Edition, 1978, p. 120-121, and, USDA, **Measurement of U.S. Agricultural Productivity: A Review of Current Statistics and Proposals for Change,** Economics Statistics and Cooperative Service, Technological Bulletin No. 16140, Washington, D.C., 1980.

Here, base year prices are used to weight the quantities of inputs in 1950 and 1975. Input quantities are seen to have increased by 57 percent over the period 1950 to 1975. The estimate of total factor productivity given these input indices is obtained by:

Year	Output Indices	Input Indices	Ratio	Productivity Indices
1950	57	100	57/100=.57 -----	100
1975	98	157	98/157=.62 -----	109

Productivity increases by 9 percent between the 1950 base period and 1975.

However, the selection of 1950 prices as weights was arbitrary; the analyst could just as easily have selected 1975 prices as weights in the total input formula.[1] If the price for labor was $2.50 per hour and non-labor inputs cost $120.00 per unit in 1975 the above tabulations could be repeated with the following results:

Year	Output Index	Labor (hours)	Labor Wage	Non-labor Input Index	Price for Non-labor
1950	57	1161	$2.50	60	$120.00
1975	98	249	$2.50	110	$120.00

The total input indices constructed using 1975 price weights are:

Year	Labor	Non-labor	Input Index
1950	1161 X $2.50 +	60 X $120.00 =	$10,102 --- 100 (base year)
1975	249 X $2.50 +	110 X $120.00 =	$13,822 --- 137

---

[1] This formulation is known as the Paasche index and may be shown algebraically as:

$$\frac{\Sigma\, Q_n\, P_n}{\Sigma\, Q_o\, P_n} \times 100$$

Total factor productivity indices become:

Year	Output Indices	Input Indices	Ratio	Productivity Indices
1950	57	100	57/100 = .57 ---	100
1975	98	137	98/137 = .72 ---	126

Simply by changing the weights used in the aggregation process the estimated change in productivity is 9 or 26 percent during 1950-75.

Weights and Base Period

This example is illustrative of the considerations facing the analysis and interpretation of productivity indices. There are two key issues which are raised:

(1) The selection of an appropriate base period.

(2) The fact that, given a time period, relative factor prices for respective inputs may change or bias productivity measures.

Since an index is a relative measure, the starting point is critical to the analysis. Relative factor mixes in the production process and respective factor growth rates should be understood if productivity movements over time are to be presented accurately. As relative factor prices change, agricultural producers substitute less costly inputs for more costly inputs. Consequently, component inputs' shares of the total value of inputs used is variable over time. Various techniques to adjust indices statistically have been developed via: (a) frequent adjustment of assigned factor weights; (b) averaging of weights for any two-period comparison, and, (c) the use of a Divisia or variable weight index. The Divisia method is often recommended as it is a weighted sum of growth rates composed of the component input shares in the total value of inputs used. However there is no consensus regarding choice of a weighting system

Input Measurement

Problems of empirical application concerning index calculation also affect productivity analyses. Accurate physical measurement of all relevant factors influencing the production process in agriculture is not always possible. Such questions as how to incorporate above-average rainfall or the contribution of managerial knowledge gained from agricultural research are difficult to ascertain. Though these examples are unquestionably vital factors to productivity growth, their measurement involves less than precise estimates of their role in the production process.

Input Valuation

The valuation of all inputs and outputs may reflect only market prices paid for their use by individual producers. Such estimates do not accurately portray the value of inputs and outputs in terms of *social* pricing. This is especially important on a national or provincial scale where a number of farm inputs are subsidized through public assistance programs, tax concessions, etc. which properly represent the real cost of these resources. For example, where farm fuel is subsidized, this subsidy should be included in the calculation of the true cost of this input to agriculture. Included in this valuation issue are problems associated with translating *stock* values for productive inputs into *flow* values. That is, converting values for capital items such as buildings and machinery into annual investment costs.

Time Frame

Finally, selection of an appropriate time frame over which to measure productivity changes has implications for the way in which productivity measures can be used. For example, to properly address issues related to natural resource management, a long run period would be desired in order to measure the quality and status of the productive resource for planning/policy purposes. A twenty year perspective would probably provide inadequate and misleading information regarding resource use.

From an examination of the literature covering productivity measurement and related methodological issues, it is clear that such analysis cannot be treated as a straightforward number-generating exercise. The following subsection deals with a number of Canadian attempts at productivity measurement. Though not directly related to the Alberta situation, they are indicative of the problems and issues raised in the foregoing. They also serve as bases for comparison with estimates presented in subsection 4.4 of this report.

4.3 CANADIAN ESTIMATES

Agricultural productivity estimates for Canada and/or the Western provinces have been undertaken by Furniss[1], Shute[2], Islam,[3] and Brinkman and Prentice.[4] (Table 4.1)

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[1] Furniss, I.F., "Productivity of Canadian Agriculture, 1935 to 1960: A Quarter Century of Change", **Canadian Journal of Agricultural Economics**, Vol.XII,No.2, 1964; Furniss, I.F., "Productivity Trends in Canadian Agriculture, 1935-1964",**Canadian Farm Economics**, Vol. I, No.1, April 1966, and; Furniss, I.F., "Agricultural Productivity in Canada: Two Decades of Gains",**Canadian Farm Economics**, Vol. 10, No. 6, December 1970.

[2] Shute, D.M., "National and Regional Productivity of Canadian Agriculture, 1961-1974", **Canadian Farm Economics**, Vol. 10, No. 6, December 1975.

[3] Islam, T., "Input Substitution and Productivity Change in Canadian Agriculture," Unpublished, Ph.D. Thesis, University of Alberta, Department of Economics, Edmonton, 1982.

[4] Brinkman, G.L., and B.E. Prentice, **Multifactor Productivity in Canadian Agriculture: An Analysis of Methodology and Performance, 1961-1980**, Working Paper, Regional Development Branch, Agriculture Canada, Ottawa. (forthcoming)

Table 4.1

SUMMARY OF AGRICULTURAL PRODUCTIVITY ESTIMATES, CANADA

(Annual Percent Change)

Researcher	Period Analyzed	Farm Output Growth	Prod'n Input Growth (percent)	Productivity Growth
Furniss	1935-60 (Canada)	2.3	-.3	2.6
	1935-64 (Canada)	1.9	-.3	2.2
	1946-64 (Canada)	1.95	-.5	2.6
	1950-69 (Canada)	2.3	.4	1.9
	1960-69 (Canada)	3.6	1.1	2.5
Shute	1961-74 (Canada)	2.04	1.17	.86
	1962-74 (Canada)	1.25	1.18	.07
	1961-74 (Prairies)	2.64	1.46	1.17
	1962-74 (Prairies)	1.10	1.44	-.35
Islam	1961-78 (Canada)	2.01	.19	1.83
	1962-78 (Canada)	1.52	.22	1.31
	1961-78 (Western Canada)	3.27	.79	2.48
	1962-75 (Western Canada)	2.52	.82	1.70
Brinkman & Prentice	1962-72 1968-80 (Canada)	n.a	n.a	1.71 1.07
	1962-72 1969-80 (Western Canada)	n.a	n.a	1.72 1.05

Sources: I.F. Furniss, D.H. Shute, T.Islam, and G.L. Brinkman and B.E. Prentice, op. cit..

Furniss found that in all cases total agricultural productivity change in Canada was positive and growing at a rate of approximately 2 percent per year.

In an update of the earlier work by Furniss, Shute examined agricultural productivity trends for Canada and the regions. Productivity change was found to be positive (although very small) for Canada but slightly negative for the Prairie provinces over the 1962 to 1974 period (-.35 percent per year). This decrease in the west was attributed to much higher rates of increase for farm inputs--especially land--than for outputs (1.4 percent versus 1.1 percent annually respectively). With the inclusion of 1961 (a drought year) in the calculations however, the rate of productivity change was found to be positive for both Canada and the Prairies(.86 percent and 1.17 percent respectively).

More recently, Islam attempted to estimate agricultural productivity for Western Canada and Canada using Divisia or flexible weight indices. The advantage of using flexible weights is that it allows for changing factor and output shares over time (eg. factor substitution). Its disadvantage is that the method requires price and quantity data for both inputs and outputs for each year in the time period. Empirical estimation is a difficult task. Islam found productivity to be positive over all periods examined for both Western Canada and Canada. Even more recently, Brinkman and Prentice have also re-calculated (and updated) earlier productivity estimates. They have found in particular that the trend in productivity growth in the 1970's did not keep up with the rate of growth in the 1960's. The authors attribute this to a levelling off in real expenditures for agricultural research, beginning in the early 1970's.

4.4 ALBERTA ESTIMATES

Agricultural productivity estimates for Alberta were estimated using Laspeyres weighted quantity indices to measure total factor productivity. Secondary data on farm input use and farm output were obtained in published form from Alberta Agriculture.[1] Input data were first deflated by their corresponding price index (1971=100) while output values were deflated by the agricultural product price index (1971=100). The individual farm operating expenses were aggregated into related variables representing land, machinery, labor, fertilizer, 'other' and public expenditure input categories. The output index was calculated by summing values for livestock and crop production.[2] The component input variables and output measure are given in Table 4.2.

The total input and output variables were indexed relative to a base year of 1971. The corresponding indices of output, input and total factor productivity are presented in Table 4.3.

Perhaps what is more important than the table numbers themselves is the fact that the methodology employed illustrates how a number of "refinements" might be introduced into the analysis. Also, the approach taken permits an overview of how these refinements impact (through an accompanying sensitivity analysis) on the resulting productivity estimates. Our refinements include:

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[1] Alberta Agriculture, **A Historical Series of Agricultural Statistics for Alberta**, Agdex #850, Edmonton, 1969; Alberta Agriculture, **op. cit.**, supplement, Edmonton, 1972-80.

[2] Possible double counting of output values may have occurred since no adjustment was made for the value of alfalfa and barley fed to livestock.

(a) extending the time frame to 1930-80

(b) determining the value of all labor inputs, adjusted for qualitative changes over time

(c) inclusion of a social cost into the total annual cost of land, re: land depreciation via land degradation

(d) inclusion of net public costs (e.g. research) into the total cost estimates of input use

In addition to the total output index, a series of four total input indices were constructed to permit an assessment of the relative significance of the above refinements to estimates of total factor productivity. Estimation began with a base case corresponding to output, input Series 1A and productivity Series 1A in Table 4.3. Alternative configurations of the input costs are represented by input Series 1B through 1D. These additional estimates are introduced through a sensitivity analysis following a discussion of base case results.

4.4.1 Base Case

Base case total factor productivity measures over the period 1930 to 1980 were calculated from the indices shown in Columns (1), (2) and (6) in Table 4.3 (i.e. Column (1) ÷ Column (2) = Column (6)). The outputs used to form the total output index are total cash receipts to crop and livestock production. This measure was used for all total factor productivity estimates.

Farm inputs contained in the total input index aggregation included estimates representing land, labor, machinery, fertilizer, other (or miscellaneous farm inputs) and net public expenditures (including R & D and direct transfer payments) in the farm sector.

Table 4.2

SUMMARY OF REAL OUTPUT & TOTAL RESOURCE USE IN ALBERTA AGRICULTURE, 1930-1980

(\$ Millions 1971)

Year	OUTPUT	INPUTS									
								INPUT TOTALS			
	(1)	Land (2)	Labor (3)	Machinery (4)	Fertilizer (5)	Other (6)	Public (7)	Series #1A (8)	Series #1B (9)	Series #1C (10)	Series #1D (11)
1930	431743	191059	682053	137686	10	63733		1074561	1074561	883482	883482
1931	412812	185799	852670	120887	47	60740		1220143	1220143	1034344	1034344
1932	437394	178628	981116	115781	170	56633		1332328	1332328	1153700	1153700
1933	318322	182575	1013233	113057	93	42777		1361735	1361735	1179160	1179160
1934	339090	172673	1002848	111234	177	63382		1350314	1350314	1177641	1177641
1935	347136	165139	967320	106695	412	58732		1298298	1298298	1133159	1133159
1936	299446	160290	936566	103075	349	61489		1261769	1261769	1101479	1101479
1937	271512	154577	925460	107310	479	74956		1262782	1262782	1108205	1108205
1938	375297	143194	899337	105991	542	78603		1227667	1227667	1084473	1084473
1939	411377	153227	854402	109697	411	82333		1200070	1200070	1046843	1046843
1940	408023	145822	738163	121047	592	84625		1090249	1090249	944427	944427
1941	444695	135187	650462	127594	444	79924		993611	993611	858424	858424
1942	456191	138717	512011	136803	562	117380		905473	905473	766756	766756
1943	460517	146507	420640	142822	450	109886		820305	820305	673798	673798
1944	577765	157133	367060	149360	610	123923		818086	818086	660953	660953
1945	426657	165451	347259	167188	1072	112057		793027	793027	627576	627576
1946	372869	173686	344253	177547	1232	126753		823471	823471	649785	649785
1947	427401	182255	350500	189590	1707	137428		861480	861480	679225	679225
1948	481435	193743	352383	204060	2059	126075		878320	878320	684577	684577
1949	480239	197070	344129	210497	2926	109127		863751	863751	666681	666681
1950	370663	187155	354826	236464	3368	107131		888944	888944	701789	701789
1951	420380	180019	352704	238845	3914	110697		886179	886179	706160	706160
1952	542312	176039	305939	246746	3369	104162		836255	836255	660216	660216
1953	550542	216967	312296	262039	4005	91807		887114	887114	670147	670147
1954	464579	204528	291531	262155	3118	84039		845371	845371	640843	640843
1955	462996	196946	308160	263083	2709	99269		870167	870167	673221	673221
1956	544355	201709	313907	255811	3102	103521		878050	878050	676341	676341
1957	549631	200811	303200	249436	3884	97350		854679	854679	653868	653868
1958	602511	218147	301330	243545	4852	108177		876051	876051	657904	657904
1959	577333	221417	304470	243866	6433	113406		889592	889592	668175	668175
1960	594232	223529	300827	244573	7460	113824		890213	890213	666684	666684
1961	600575	225941	296433	241176	9343	122306		895199	895199	669258	669254
1962	587330	235889	298968	251575	11458	133270		931160	931160	695271	695271
1963	550308	239323	290000	257646	15232	139315		941516	941516	702193	702193
1964	659624	243764	286864	262520	20865	143076		957089	957089	713325	713325
1965	684359	238933	275914	271453	23178	147426	7783	964687	956904	725754	717971
1966	735097	242628	259312	283607	27806	164260	6242	983853	977611	741225	734983
1967	773167	241536	265706	299472	37675	158008	7445	1009842	1002397	768306	760861
1968	810872	239849	252887	304444	42132	153430	10717	1003459	992742	763610	752893
1969	718573	226707	265910	305479	28631	147210	19479	993416	973937	766709	747230
1970	715344	233737	257126	283707	23002	149887	25375	972834	947459	739097	713722
1971	803673	259140	251597	279742	31277	156194	30792	1008742	977950	749602	718810
1972	756495	255876	241637	302029	32103	155162	27290	1014097	986807	758221	730931
1973	632574	287787	240132	327772	41713	187456	9943	1094803	1084860	807016	797073
1974	730902	305936	237241	361141	53432	210997	14468	1183215	1168747	877279	862811
1975	859253	325116	238427	377727	62811	201597	24017	1229695	1205678	904579	880362
1976	914301	310002	270453	384168	57582	197579	42469	1262253	1219784	952251	909782
1977	989709	306195	255708	406081	53598	263404	76303	1361287	1284984	1055092	978789
1978	994031	318514	256690	426109	67242	268251	52563	1389369	1336806	1070855	1018292
1979	1064987	337402	250226	445790	77712	307148	45015	1463293	1418278	1125891	1080876
1980	1100348	339006	261674	449070	66201	314770	45643	1476364	1430721	1137358	1091715

Sources: Column (1): Table C.2
Column (2): Table C.3
Column (3): Table C.4
Columns (4), (5), (6): Table C.5
Column (7): Table C.6

Column (8): Basic data (Series #1A), with related public expenditures, (Column 7), and land degradation costs.

Column (9): Basic data (Series #1B), without related expenditures.

Column (10): Basic data (Series #1C), without land degradation costs

Column (11): Basic data (Series #1D), without land degradation costs and without public expenditures.

Table 4.3

INDICES OF AGRICULTURAL OUTPUT, INPUT AND TOTAL FACTOR PRODUCTIVITY, ALBERTA 1930-1980

(1971 = 100)

Year	Output	Input[a]				Productivity			
		Series 1A[b] (2)	Series 1B (3)	Series 1C (4)	Series 1D (5)	Series 1A (6)	Series 1B (7)	Series 1C (8)	Series 1D (9)
	(1)								
1930	53.7	106.5	109.9	117.9	122.9	.504	.489	.456	.437
1931	51.4	121.0	124.8	138.0	143.9	.425	.412	.372	.357
1932	54.5	132.1	136.2	153.9	160.5	.412	.400	.354	.339
1933	39.6	135.0	139.2	157.3	164.0	.293	.284	.252	.241
1934	42.2	133.9	138.1	157.1	163.8	.315	.306	.269	.259
1935	43.2	128.7	132.8	151.2	157.6	.336	.325	.286	.274
1936	37.3	125.1	129.0	146.9	153.2	.298	.289	.254	.243
1937	33.8	125.2	129.1	147.8	154.2	.270	.262	.229	.219
1938	46.7	121.7	125.5	144.7	150.9	.384	.372	.323	.310
1939	51.2	119.0	122.7	139.7	145.6	.430	.417	.367	.351
1940	50.8	108.1	111.5	126.0	131.4	.470	.455	.403	.386
1941	55.3	98.5	101.6	114.5	119.4	.562	.545	.483	.463
1942	56.8	89.8	92.6	102.3	106.7	.632	.613	.555	.532
1943	57.3	81.3	83.9	89.9	93.7	.705	.683	.637	.611
1944	71.9	81.1	83.7	88.2	92.0	.886	.859	.815	.782
1945	53.1	78.6	81.1	83.7	87.3	.675	.655	.634	.608
1946	46.4	81.6	84.2	86.7	90.4	.568	.551	.535	.513
1947	53.2	85.4	88.1	90.6	94.5	.623	.604	.587	.563
1948	59.9	87.1	89.8	91.3	95.2	.688	.667	.656	.629
1949	59.8	85.6	88.3	88.9	92.7	.698	.677	.672	.644
1950	46.1	88.1	90.9	93.6	97.6	.523	.507	.493	.472
1951	52.3	87.8	90.6	94.2	98.2	.595	.577	.555	.532
1952	67.5	82.9	85.5	88.1	91.8	.816	.789	.766	.735
1953	68.5	87.9	90.7	89.4	93.2	.779	.755	.766	.735
1954	57.8	83.8	86.4	85.5	89.2	.690	.669	.676	.648
1955	57.6	86.3	89.0	89.8	93.7	.668	.647	.641	.615
1956	67.7	87.0	89.8	90.2	94.1	.778	.754	.751	.720
1957	68.4	84.7	87.4	87.2	91.0	.807	.783	.784	.752
1958	75.0	86.8	89.6	87.8	91.5	.863	.837	.854	.819
1959	71.8	88.2	91.0	89.1	93.0	.815	.790	.806	.772
1960	73.9	88.2	91.0	88.9	92.7	.838	.812	.831	.797
1961	74.7	88.7	91.5	89.3	93.1	.842	.816	.837	.803
1962	73.1	92.3	95.2	92.8	96.7	.792	.768	.788	.756
1963	68.5	93.3	96.3	93.7	97.7	.734	.711	.731	.701
1964	82.1	94.9	97.9	95.2	99.2	.865	.839	.863	.827
1965	85.2	95.8	97.8	96.8	99.9	.890	.870	.880	.853
1966	91.5	97.5	100.0	98.9	102.3	.938	.915	.925	.895
1967	96.2	100.1	102.5	102.5	105.9	.961	.939	.939	.909
1968	100.9	99.5	101.5	101.9	104.7	1.014	.994	.990	.963
1969	89.4	98.5	99.6	102.3	104.0	.908	.898	.874	.860
1970	89.0	96.4	96.9	98.6	99.3	.923	.919	.903	.896
1971	100.0	100.0	100.0	100.0	100.0	1.000	1.000	1.000	1.000
1972	94.1	100.5	100.9	101.1	101.7	.936	.933	.931	.926
1973	78.7	108.5	110.9	107.7	110.9	.725	.710	.731	.710
1974	90.9	117.3	119.5	117.0	120.0	.775	.761	.777	.758
1975	106.9	121.9	123.3	120.7	122.5	.877	.867	.886	.873
1976	113.8	125.1	124.7	127.0	126.6	.909	.912	.896	.899
1977	123.1	134.9	131.4	140.8	136.2	.913	.937	.875	.904
1978	123.7	137.7	136.7	142.9	141.7	.898	.905	.866	.873
1979	130.0	145.1	145.0	150.2	150.6	.896	.897	.866	.863
1980	136.9	146.6	146.3	151.7	151.9	.935	.936	.902	.901

[a] Each series corresponds to those input totals used in sensitivity testing.

[b] Base case input, output, and productivity indices

Notes:

Column (1): Output measured as the total of crop and livestock cash receipts.

Column (2): Input index used in base case. Data and derivation of this series are presented in Appendix C, Table C.1.

Column (3): Input index composed of the base case data *excluding* public expenditures. Details in Appendix C, Tables C.1 and C.6.

Column (4): Input index composed of the base case data *excluding* land degradation costs. Details in Appendix C, Tables C.1, C.3 and C.3(a).

Column (5): Input index composed of the base case data *excluding* public expenditures *and* land degradation costs. Details in Appendix C, Table C.1.

Column (6): Column (1) ÷ Column (2)

Column (7): Column (1) ÷ Column (3)

Column (8): Column (1) ÷ Column (4)

Column (9): Column (1) ÷ Column (5)

Land Costs

The land variable was modified to include capital values of buildings and related expenses. Not only annual expenditures and repairs plus building depreciation were included but a real interest rate of 5% per year was applied to the capital value of land and buildings. This figure was used in order to adjust traditional *stock* values into *flow* values for the purposes of incorporating all relevant opportunity costs to agricultural resources used in farm production. Further, costs attributable to depreciation of land as a productive asset were also estimated. The valuation of these costs was based on losses incurred through soil degradation (i.e. salinity, fertility and erosion losses).

Based on available literature dealing with the subject of soil degradation in Alberta[1] ample evidence exists to support this phenomenon as a *bona fide* cost of production in agriculture. Treatment of this cost in the analysis is similar to that for machinery depreciation. An attempt was made to assign a "reasonable" dollar amount to this on-going (and growing) cost to the agricultural industry and society in general. The general magnitude of these (social) costs to Alberta agriculture were quantified in order to reflect:

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[1] McGill, W.B., **Soil Fertility and Land Productivity in Alberta,** Environment Council of Alberta, Edmonton, July 1982. Other studies readily available on this topic include:

(a) Campbell, C.A., E.A. Paul and W.B. McGill, **Effect of Cultivation and Cropping on the Amounts and Forms of Soil N,** Proceedings of the Soil Science Workshop, Edmonton, Alberta, February, 1981.

(b) McGill, W.B., C.A. Campbell, J.F. Dormaar, E.A. Paul and D.W. Anderson, **Soil Organic Matter Losses in Agricultural Land: Our Disappearing Heritage,** Proceedings of the Soil Science Workshop, Edmonton, Alberta, February 1981.

(c) PFRA, Soil and Water Conservation Branch, **Land Degradation and Soil Conservation Issues on the Canadian Prairies: An Overview,** DREE/PFRA, November 1982.

(1) the commercial cost of 75 percent of potential crop production on saline areas for both dryland and irrigated soils (200,000 ha.)

(2) the commercial cost of 85 percent of potential crop production on eroded areas (by wind and water) based on 10 percent of all cultivated land

and (3) the commercial cost of augmenting chemical fertilizer applications by 80 percent to compensate for declining soil fertility levels.

The estimates employed herein constitute a very crude first approximation of the real costs of soil degradation during 1930-1980. Accurate quantitative estimates of the area affected by salinity and erosion in Alberta are simply not available. Although it is readily acknowledged that soil "mining" has occurred throughout our brief history, it is still very unclear what rate of soil mining during 1930-1980 might actually have represented a social optimum.[1]

A more detailed treatment of estimation procedures is presented in Appendix C, Table C.3 and C.3(a).

Labor Costs

The labor component of the total input index includes wages to hired labor plus estimated wages to farm operators plus imputed wages to family labor. Since published data does not exist regarding the unpaid family labor force, imputed wages assumed both a fixed percentage of total employment and proportional valuation. The assumptions behind this valuation procedure were intended to allow for qualitative changes (e.g. education levels) and lifestyle changes for workers over time (e.g. no. of hours worked). Valuation of the labor input proceeded as follows: [2]

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[1] Assuming reversibility of this mining process is still possible, this question is roughly equivalent to the question of how quickly forests should be harvested. The answer largely depends on the social time preference of society.

[2] The methodology parallels that of B.E. Prentice and G.L. Brinkman, **The Value of Agricultural Research in Ontario,** OAC/University of Guelph, July 1982.

(1) operator earnings were assumed to equal the wage rate for hired labor, with board. This implies no opportunity cost for owner-operators or, that if they were forced to work elsewhere they could be employed at rates at least equal to hired labor with board levels.

(2) unpaid family labor was assumed to represent a similar importance for Alberta farm labor force to that of Canadian agriculture in general. The imputed earnings to unpaid family members was estimated using 70% of the wage rate for owner-operator.

(3) hired farm labor was included based on historical data published by Alberta Agriculture cited in tabled references.

Documentation is provided in Appendix C, Table C.4.

Machinery, Fertilizer and Other Costs

Machinery costs covered cash operating expenses, depreciation and an estimate of the opportunity cost of capital invested in machinery and equipment. The opportunity cost was based on a real rate of interest of 5% of the capital value of machinery and equipment per year. This approach is the same as applied to the land component. Fertilizer expenses were extracted directly from the Alberta Agriculture data cited previously. Similarly 'other crop expenses' comprise the remainder of relevant input items essential to the calculation of the total input index presented in the base case, Table 4.3.

All input variables were deflated to constant 1971 dollars prior to aggregation into the total input measure. Once added the total was transformed to a 1971 base year index by dividing all historical observations by the 1971 value.

This input total (Series 1A) formed the denominator in the ratio of base case total output index over total input index. The resulting total factor productivity index provides the starting point for an analysis of historical productivity changes in Alberta. The respective base case indices are shown graphically in Figure 4.1.

Annual rates of productivity growth for the period 1930-80 and by decade are given in Table 4.4. After a sharp decline during 1930-39, productivity climbed sharply through the 1940's and 1950's, began to decline in the 1960's and tended to level off during the 1970's. Overall, a growth rate of 2.04 percent per year prevailed during the time frame observed. These figures represent as full an accounting of appropriate costs as possible within the constraints of methodology and data available. Though output growth greatly outpaced input increases from 1940 through 1970, declines in the 1930's (due to climatic influences) and input gains in the 1970's resulted in overall productivity improvements at the 2 percent level. Adjustments to cost accounting procedures, especially from a social perspective are attempted through a series of sensitivity tests (Series 1B to 1D in Table 4.2).

4.4.2 Sensitivity Analysis

Using the base case as a starting point, alternative input combinations were tested to determine the impact on the rates of total factor productivity growth. The first scenario is designated as Series 1B. This measure represents the base case except that public expenditures associated with the total input index have been excluded from the calculations. Since public expenditures represent net social costs, their removal acts to reduce the magnitude of the

Figure 4-1

INDICES OF AGRICULTURAL OUTPUT, INPUTS AND TOTAL FACTOR PRODUCTIVITY

ALBERTA 1930 TO 1980

(1971 = 100)

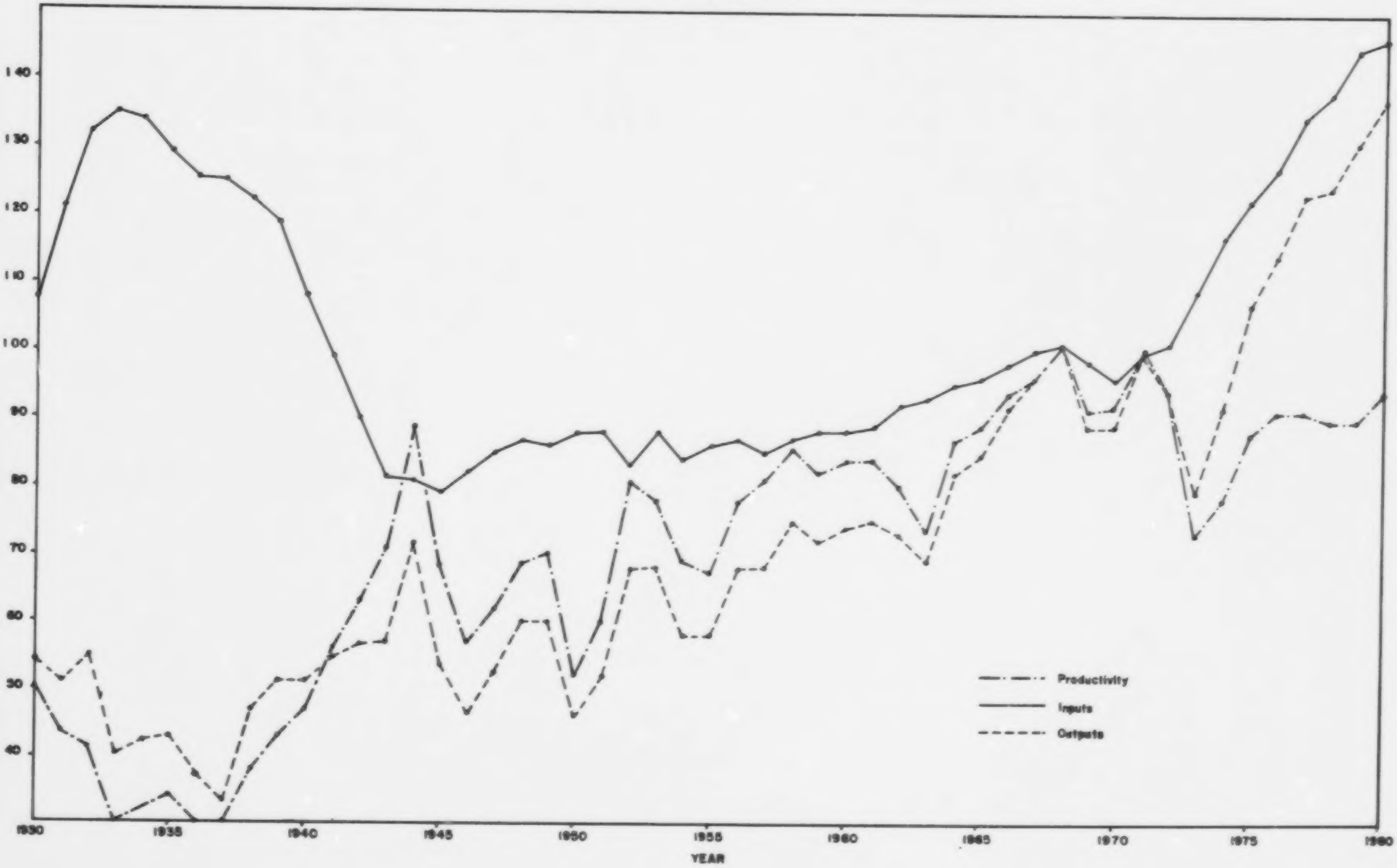

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Table 4.4
ANNUAL RATES OF GROWTH IN OUTPUT, INPUT, AND TOTAL FACTOR PRODUCTIVITY ALBERTA 1930-1980 (%)

Indices [a]	1930-39	1940-49	1950-59	1960-69	1970-80	1930-80
OUTPUT						
Series 1 [b]	-2.19	.46	4.04	3.76	4.79	2.14
INPUT						
Series 1A [b]	.30	-1.94	.02	1.42	4.67	.09
Series 1B	.30	-1.94	.02	1.23	4.50	.02
Series 1C	.86	-3.27	-.55	1.75	5.07	-.02
Series 1D	.86	-3.27	-.55	1.49	4.86	-.03
PRODUCTIVITY						
Series 1A [b]	-2.49	2.45	4.02	2.30	.11	2.04
Series 1B	-2.49	2.45	4.02	2.50	.27	2.11
Series 1C	-3.02	3.86	4.62	1.98	-.27	2.38
Series 1D	-3.02	3.86	4.62	2.23	-.07	2.47

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[a] Based on indices presented in Table 4.2.

[b] Base case.

total input value in the denominator of the total factor productivity ratio. Rates of productivity growth are shown to increase for the periods 1960-69, 1970-80 and marginally overall.

Series 1C retained net public expenditures but excluded land costs. Results show that expenses related to fixed capital resources of land and buildings and the quality of the land base itself make a significant impact on estimates of productivity growth. The flow of annualized costs of maintaining these capital resources represent a significant proportion of total input costs. Removal of these costs causes growth rates in the input index to decline by 122% while the corresponding productivity rate increases by 17% over base case levels during 1930-1980. The implied elasticity value is .14.

Series 1D is a scenario which combines the adjustments of Series 1B and 1C. That is, both land costs and public costs are excluded from index measurement. The costs remaining constitute essentially total private costs associated with farm output. The total input index is at its lowest level in terms of magnitude and lowest rate of growth relative to changes in output shown in Table 4.2. The net result is a 21% gain in productivity growth in relation to a 133% decline in total input growth for an elasticity value of .16. The impact of the inclusion of appropriate valuation of true social plus private input costs is significant in terms of identifying true measures of productivity trends.

Making these "pluses" and "minuses" may or may not improve the accuracy of the TFP indices *per se*. The big advantage of explicitly considering many of these changes in the analysis is that it facilitates our understanding of *relative impacts*. In a policy-making context, what is the *relative* significance of continued soil degradation vis-à-vis future agricultural productivity levels and total production levels? This is the exclusive focus of Section VI following.

4.5. SUMMARY

The preceding historical productivity estimates for Alberta agriculture are not, repeat *not*, very accurate. In the construction and interpretation of indices used to measure productivity performance the points which should be emphasized are these:

1. Indices of total factor productivity are much more indicative of industry performance (as calculated herein) than partial factor productivity measures, e.g. output/person or yields/ha.
2. Nevertheless, there are numerous practical/methodological difficulties inherent in the construction of TFP indices. These include:
   - accurate physical measurement of all inputs and outputs in the production process, e.g. the contribution of above-average rainfall or agricultural research
   - accurate valuation of all inputs and outputs in terms of *social* pricing, e.g. if farm fuel purchases are subsidized, what is the true cost of this input to agriculture? A major difficulty here is also encountered translating *stock* values into *flow* values e.g. capital into an annual investment cost.
   - selection of a base period. Since an index is a *relative* measure, this too is critical. (Hence the debate over the adequacy of the Laspeyres, Divisia, or other indexing procedures.)
   - determining an appropriate time frame. To properly address natural resource management issues (especially for renewable resources), a twenty year perspective is obviously very inadequate. It could also be very misleading.
3. Total factor productivity analysis is essentially a rudimentary *benefit-cost analysis* over time. Most likely the accuracy of a TFP index can be considered as very similar, i.e. within a confidence limit of + 20 percent. The same general caution applies - *user beware*.

SECTION V

THE ROLE OF ALBERTA-CANADA RESEARCH

5.1. INTRODUCTION

In November and December of 1982, interviews were conducted with research scientists at provincial and federal research facilities at Vegreville, Beaverlodge, Lacombe, Brooks, Lethbridge, Swift Current and Regina. The purpose of these interviews was to get some idea of future agricultural productivity potential, output and resource use as viewed by those who are directly involved in the ultimate achievement of new productivity gains. Further, an attempt was made to get scientists to estimate the time-frame for successful completion of their individual projects and the time required for their results to be adopted by the farming community.

5.2 SURVEY FINDINGS

Before a detailed discussion of our survey findings, a few general, but significant observations should be made:

- No major breakthrough in agricultural research is expected before the turn of the century. Gains to be made will likely come in incremental steps.
- At the same time, research scientists are optimistic about future productivity gains in agriculture. Of the forty-one scientists expressing an opinion about future productivity levels, thirty-one (76%) felt that productivity would increase in the forseeable future. Ten scientists (24%) felt that productivity levels would plateau as input costs continued to rise. None felt that productivity in agriculture would decline.
- Researchers at the more northerly research facilities are very optimistic about the agricultural potential of the north. In one interview the challenge of northern

agriculture now was likened to the challenge of agriculture in southern areas in the early 1900's.

- The research undertaken by those scientists interviewed is very much problem or goal oriented. With a few exceptions (e.g. plant and animal breeding, bio-control and soils research) research projects tended to be 5 years or less in duration with results to be expected within that time frame.
- Concern exists within the research establishment that without increases in research funding in the near future, important research projects may have to be curtailed or cancelled. While many acknowledged a need for more staff, few expected any increases within the next five years.

5.2.1 Productivity-Increasing Versus Maintenance Research

Both productivity–increasing and maintenance research are vital to the continued viability of the agriculture sector in Alberta. While the distinction can sometimes become "fuzzy", in general we consider maintenance research to be that which is directed towards removing obstacles which interfere with a plant or animal reaching its physical potential. Productivity–increasing research is aimed at increasing the physical potential of crops or livestock. Examples of maintenance research include weed control, pest management and research to maintain or restore the quality of the land base. The most obvious example of productivity-increasing research is breeding for higher yielding and more efficient plants and animals.

Of forty-one scientists interviewed, eighteen (40%) considered their research as being maintaining; twenty-seven (60%) categorized their efforts as potentially productivity increasing.[1]

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[1] Four researchers considered their work to be both productivity increasing and maintenance in nature, thereby accounting for the 45 responses.

The relatively large number of scientists involved in maintenance research in our sample underlines its importance in the overall agricultural research effort. The two types of research in effect complement one another.

5.2.2 Research Focus and Related Research

Research undertaken at the various research facilities tends to be specific to the region of the province where the institution is located. Federal research stations in particular have mandates to deal with regional agricultural problems. For example, the facility at Beaverlodge has a mandate to deal with the problems of northern agriculture, Lacombe focuses on south-central Alberta and Lethbridge investigates the problems and potentials of dryland and irrigated agriculture in the south. A considerable amount of regional spillover does occur and, in some cases, stations will work jointly on projects of mutual interest.

Provincially, Alberta has a relatively good regional distribution of research facilities. These serve to augment and complement the Federal agricultural research facilities. For example, the University of Alberta augments Lacombe and the (relatively) new Alberta Environmental Centre in Vegreville augments the Beaverlodge research station.

All scientists interviewed were aware of similar (although not necessarily identical) research to theirs being undertaken elsewhere. In many cases identical work was being conducted elsewhere in the province. For example, cereal breeding is being done at Beaverlodge, Lacombe, Swift Current and Lethbridge. While this appears to be a duplication of effort, scientists point out that because of differences in climate, soils, topography and other factors, such "duplication" is not only useful, but necessary. Varieties that perform well in one region may do poorly in another. In an historical context, the importance of region-specific varieties is evident. Red Fife wheat was adequate for growing conditions in Ontario but it was not until the development of

Marquis, an earlier maturing variety, that wheat production on the Prairies really became viable.

5.2.3 Time Frame

As indicated previously, much of the research currently underway at both provincial and federal research facilities is short-term (1-5 years), problem (and goal) oriented research. Some research areas, such as weed control and plant pathology do not have a time frame in the strict sense of the word. This is on-going research and scientists tend to concentrate on a particular problem for a few years to control a disease or weed and then move on to new problems. For example, Verticillium wilt in alfalfa was a relatively unimportant disease until recently. Now the disease threatens the industry. Accordingly, research staff have been allocated to address this problem.

The anticipated time frame for successful completion of research projects currently underway by those surveyed is presented in Table 5.1. Many projects are short-term (less than five years). Plant and animal breeding tended to have the longest anticipated time frame for success due to the number of crosses required and the time lags associated with making each cross. At the same time, it is the area of plant and animal breeding which appears to hold much of the promise for future potential gains in agricultural productivity.

5.2.4 Adoption Rates

Crucial to any future increases in agricultural productivity is the rate at which new technology is transferred from the research station to on-farm use. Researchers surveyed tended to have an appreciation of the difficulties inherent in translating research into widespread improvements in farm practices but, in most cases, were still able to estimate the time lag between completion of research and adoption. On several occasions scientists commented that considerable new technology remains "on the shelf" waiting to be adopted. At the same time, others noted that they felt that farmers in Alberta were relatively quick to adopt *if* the economics of the new technology were favorable.

Table 5.1

TIME FRAME FOR SUCCESSFUL COMPLETION OF ON-GOING RESEARCH, SELECTED RESEARCH SCIENTISTS

Research Area	Number of Projects	Time Frame (years)
Biological		
Animal Breeding		
beef	1	20
swine	1	8-10
Plant Breeding		
cereals	4	8-15
canola	1	8-10
forage	1	5
Honey Bee Breeding	1	4
Crop Production/Management	14	3-10
Plant Pathology	5	2-10
Biocontrol	5	5-10+
Plant/Animal Physiology	2	5-10
Soil Science	4	5-10, on-going
Chemical		
Pesticides, herbicides	4	3-5, on-going
Mechanical	2	5-10
Informational	2	5+, on-going

In Table 5.2, researchers' estimates of the time necessary for adoption of their research findings are tabulated. The Table indicates that researchers are generally optimistic that farmers will adopt fairly rapidly. Most scientists responding hedged their answers with the caveat that actual adoption will depend upon the perceived profitability of the innovation, farmers' attitudes, and the relative improvement of the innovation over existing technologies.

Based on historical data, one suspects that the estimates of Table 5.2 may be too optimistic. For example, both Thatcher and Neepawa wheats took over ten years for the percentage of total wheat acreage planted to these crops to reach a maximum. Fertilizer and herbicide use in Alberta continues to grow after several decades. The adoption of machines such as combines and tractors was an even slower process. Likely, the estimates in Table 5.2 more closely reflect the time required for early adopters or "innovators" to take advantage of the technology; the majority would adopt at a progressively slower rate after evaluating the results of a neighbor's experiences or when more information is available through sources such as the farm press. In short, as with past technological advances, one expects the adoption curve to approximate an S-shape with the origin, slope and ceiling of the curve dependent upon the nature of the technology and a number of other social, economic and informational factors (see Section 2.5).

Table 5.2
ANTICIPATED ON-FARM ADOPTION OF CURRENT RESEARCH

Research Area	Number of Projects	Time to Adopt (years)
Biological		
Animal Breeding		
beef	1	5
swine	1	6
Plant Breeding		
cereals	6	3-5
canola	1	7
forage	1	3+
Honey Bee Breeding	1	5
Crop Production/Management	14	2-5
Plant Pathology	5	1-8
Biocontrol	5	2-4
Plant/Animal Physiology	2	3-5
Soil Science	4	5+
Chemical		
Pesticides, herbicides	4	1-10
Mechanical	2	10+
Informational	2	5

5.2.5 Impacts of Future Research

Scientists were asked to identify the input and/or output to be most affected by successful completion of their research and to estimate the magnitude of the anticipated change. In most cases those interviewed were able to estimate the probable impact of their efforts. Findings are summarized in Table 5.3.

As indicated in the Table, variables which would likely be impacted but for which no quantitative estimates are available, are identified in addition to those for which estimates are available.

In general, crop or livestock yields were the most directly impacted variables. For cereals and canola breeding, yield gains of between 3 and 10 percent over the next ten to fifteen years seem attainable. Gains of the same magnitude (i.e. approximately 5 percent) can be expected from beef and swine breeding. The time frame for genetic improvements in beef cattle may be 25 to 40 percent longer than for crop breeding.

Research relating to plant and animal diseases and pests may be misleading in terms of estimated magnitude of impact. New pests and diseases often take the place of diseases and weeds which are controlled. Actual realized yield gains may be small.

Crop production/management research includes a wide variety of research projects, such as irrigation, special crops, forage, vegetable, fruit and snow management. Yield gains of 5 to 100 percent were considered possible, depending on the project focus. Highest yield improvements were expected from research into different annual forages. Plant/animal physiology and soil research may lead to decreases in both costs and quantities of fertilizers required. If farmers can be convinced to extend their crop-summerfallow rotations, production could increase significantly. For example, it was estimated that changing from a crop-fallow to a crop-

Table 5.3
IMPACT OF RESEARCH ON OUTPUTS AND INPUTS

Research Area	OUTPUT VARIABLE IMPACTED			INPUT VARIABLE IMPACTED							
	Area	Yield	Price	Land		Labor		Machinery		Fertilizer/Chemicals	
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Biological											
Plant Breeding											
Cereals	X	+3-10%		X	X	X	X	X		X	
Canola	X	+10%		X	X	X	X	X		X	
Forages	X	+15-20%		X							
Animal Breeding											
Beef		+5%									
Swine		+5%									
Honey Bee Breeding		+15-150%									
Crop Production/ Management	X	+5-100%		X		X	X	X		X	
Plant Pathology		+3-30%								X	
Biocontrol		+5-20%									X
Plant/Animal Physiology				X				X		-25%	
Soil Science	X	X		X		X		X		X	-50%
Chemical											
Pesticides/ herbicides		+10-30%									X
Mechanical	X	+4-20%							X	X	
Informational		+10%		X							

crop-fallow rotation could increase wheat production in southwest Saskatchewan by as much as twenty-two percent.

Overall, steady but unspectacular growth in production is expected in the next two decades due to genetic improvements. Significant gains appear possible with better management techniques and use of existing knowledge (See Section IV). Plant and animal pest and disease research is vital but is unlikely to translate into significant realized yield gains over time. Machinery will continue to adapt to changing cultural practices (e.g. minimum till) but is not seen as being a leading force in future agricultural output increases.

5.2.6 Obstacles to Productivity Growth

What will be the main obstacle or limiting factor to agriculture productivity growth over time? Of the forty-one responses to this question, thirteen (31.7%) thought economic considerations (prices of inputs, prices of outputs, etc.) might prove to be the main barrier. Eleven others (26.8%) cited inadequate research staff and funding as the probable main obstacle to future productivity growth. A lack of markets for our agricultural produce was also mentioned by four scientists (9.8%).

Other, often interrelated, but less frequently mentioned obstacles include: deteriorating resource base, climate, inadequate extension/consumer education and government policies.

Some 25 of the scientists interviewed were also asked to rank what they perceived to be the four most important obstacles to continued productivity growth. Results are presented in Table 5.4. The composite index again shows economic conditions and research staff/funding to be the greatest perceived obstacles to future productivity increases. Other categories were considered relatively less important by the respondents as a group.

Table 5.4

PERCEIVED OBSTACLES TO FUTURE PRODUCTIVITY GROWTH IN AGRICULTURE

Obstacle	Ranking[a]				Composite Index[b]
	IV	III	II	I	
	(number of responses)				
Economic Conditions	10	9	3	1	74
Producer Adoption of Technology	1	–	4	4	16
Research Funding/ Staff	6	3	8	5	54
Deteriorating Resource Base	2	3	2	3	24
Inadequate Extension/ Consumer Education	–	1	1	2	7
Climate/Weather	3	5	1	2	31
Government Policies	1	1	4	6	21
Lack of Markets	2	2	2	2	20
Crop Storage	–	1	–	–	3
TOTAL RESPONSES	25	25	25	25	

[a] Rankings are presented in declining order of importance with IV indicating the greatest perceived obstacle and I indicating a lesser degree of importance.

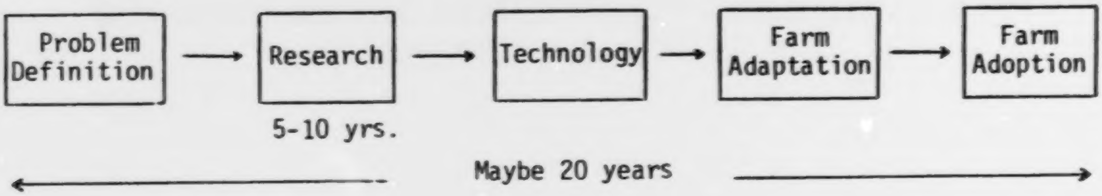
[b] The composite index is derived by multiplying the number of responses for each ranking by the implied relative importance of each ranking.
e.g. economic conditions = 10 (4) + 9 (3) + 3 (2) + 1 (1) = 74

5.2.7 High Payoff Research

All scientists were also queried as to the type of agricultural research they felt has, or would have, the highest payoff. Of thirty-eight respondents, approximately one in three (34.2%) thought that his/her area of specialty could potentially generate the highest payoff. Nine scientists (23.7%) mentioned some combination of applied research in conjunction with a management "package". Eight others (21.1%) felt that high-payoff research in agriculture was in breeding new strains and varieties of plants and animals. Greater integration of research effort among the various scientific disciplines was stressed by 13.2 percent of respondents (5 scientists). Three scientists (7.9%) each identified nitrogen fixation in cereals, and production research of all kinds as the high payoff areas in agricultural research. More effort in soil science and new cultivation methods (e.g. minimum tillage) was recommended by 5.2 percent (2 scientists) of those responding. Other high-payoff areas mentioned by individuals included greater diversification, marketing and processing research, irrigation in the North, better allocation of research resources and more basic research.

5.2.8 Summary

The preceding pages have provided some indication of the direction, time-frame and potential obstacles to agricultural research in Alberta as perceived by those actually involved in research work. What is clear is that the development of technology is a *process*, beginning with the identification of the problem to be addressed and concluding with the adaptation and eventual use of an on-farm technology. This process is described schematically by the following:


Problem Definition
Research
Technology
Farm Adaptation
Farm Adoption
5-10 yrs.
Maybe 20 years

An "overnight" research "breakthrough" by research scientists often only comes after twenty years of dedicated effort.

SECTION VI

PRODUCTION AND PRODUCTIVITY PROJECTIONS FOR ALBERTA AGRICULTURE, 1980-2030

6.1. INTRODUCTION

This Section has three basic objectives:

(1) To crudely translate projected partial productivity trends into "most likely" total productivity trends in Alberta agriculture during the next 50 years.

(2) To provide some indication of how total productivity trends might be expected to change if basic agricultural research and/or soil/water conservation programs in Alberta achieved additional public support.

(3) To further underline the methodological strengths and weaknesses of total factor productivity estimates (and accompanying growth rates) for agriculture.

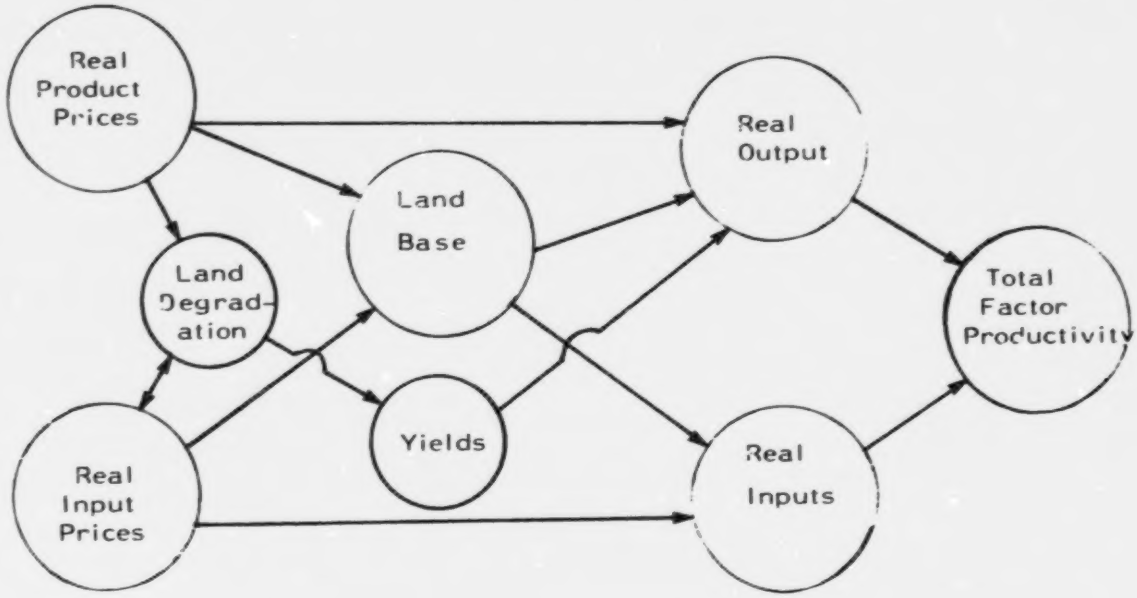
The procedure followed in this largely illustrative exercise is to construct four alternative development scenarios to represent the period 1980-2030.

Scenario A = Base Case
Scenario B = Scenario A but with an Accelerated Ag. Research Program
Scenario C = Scenario B but with an Accelerated Soil-Water Conservation Program.
Scenario D = Scenario A with both an Accelerated Ag. Research Program and an Accelerated Soil-Water Conservation Program.

6.2 BASE PROJECTIONS

The key variables and the causal relationships which impact on productivity changes in agriculture are illustrated in Figure 6.1.

Figure 6.1
SCHEMATIC REPRESENTATION OF PRINCIPAL FACTORS AFFECTING AGRICULTURAL PRODUCTIVITY

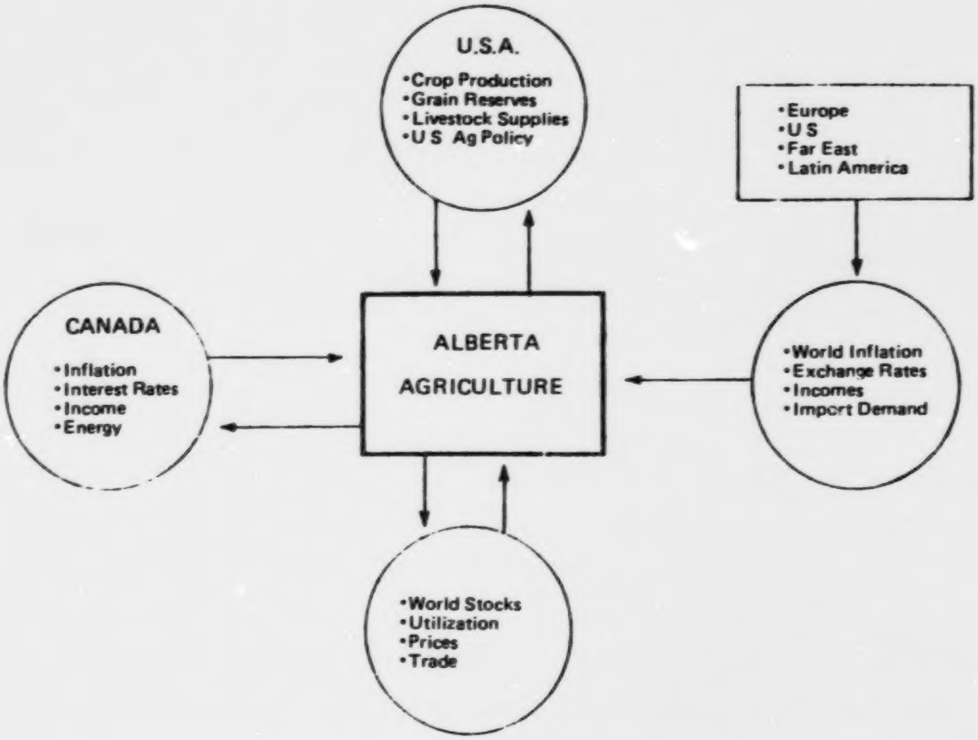

Real Product Prices
Real Output
Land Base
Land Degradation
Total Factor Productivity
Yields
Real Input Prices
Real Inputs

Sub-sections 6.2.1 through 6.2.6 following provide the essential rationale for our basic productivity projections for the years 1980-2030 calculated in Section 6.4.

6.2.1 Product and Input Prices

The difficulties inherent in making agricultural price forecasts for the next fifty years are readily apparent, as suggested in Figure 6.2.

Figure 6.2
SCHEMATIC OF ALBERTA AGRICULTURE AND INTERNATIONAL MARKET CONDITIONS


U.S.A.
•Crop Production
•Grain Reserves
•Livestock Supplies
•U S Ag Policy
•Europe
•U S
•Far East
•Latin America
CANADA
•Inflation
•Interest Rates
•Income
•Energy
ALBERTA AGRICULTURE
•World Inflation
•Exchange Rates
•Incomes
•Import Demand
•World Stocks
•Utilization
•Prices
•Trade

Obviously, the exercise is highly speculative.

Nevertheless, because future real price changes will largely dictate the *direction* of change in Alberta agriculture, the analysis is almost mandatory.

For simplicity, it is generally assumed that the real price of all major commodities traded in the international market (principle grains, beef, chemicals, machinery), are determined outside of Alberta, i.e. exogenously. Regardless of production levels or input use, competitive international base prices will largely determine the product mix, as well as the input mix (i.e. technology) adopted by farmers in Alberta agriculture.

In this context, two product price scenarios have been prepared: (1980 = 100).[1]

	Pessimistic	Optimistic
1980	100	100
1990	105	110
2000	110	120
2010	115	130
2020	120	140
2030	125	150

These real product price indices are further assumed to be accompanied by high and low real price increases for purchased inputs, respectively. This generates two even more extreme cases of the historical "cost-price squeeze" during 1980-2030: (1) narrow margins (pessimistic) and (2) wider margins (optimistic).

The accompanying input price projections are tabulated in Appendix D, Table D.1.

6.2.2 Agricultural Land Base

The extent of the agricultural land base in Alberta has been investigated in great detail by other researchers.[2]

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[1] This section borrows very heavily from a recent (very extensive) analysis of future real agricultural product/input prices in Western Canada. See: Marv Anderson & Associates, **Saskatchewan Drought Studies: Economic Study Parameters,** Study Element #2, revised, Regina, December 1982.

[2] See especially: P.S. Thompson, **The Agricultural Land Base in Alberta,** ECA, Edmonton, 1981.

Additional analysis is beyond the scope of the present study.

For the purposes of the productivity projections following, historical trends in the improved land acreage in Alberta agriculture were basically extrapolated into the future. (See accompanying Figure 6.3). This extrapolation was then adjusted to reflect different economic conditions in agriculture, i.e. narrow or wide margins. The resulting changes in the *improved* agricultural land base are expected to be as follows: (million hectares)[1]

	Pessimistic	Optimistic
1981(actual)	12.55(31.0)[1]	
1990	13.20(32.6)	13.77(34.0)
2000	13.85(34.2)	15.14(37.4)
2010	14.49(35.8)	16.52(40.8)
2020	15.14(37.4)	17.89(44.2)
2030	15.79(39.0)	19.27(47.6)

These estimates are also highly speculative. Their real significance is that an expansion in the improved land area is only assumed on existing agricultural land. And this generally implies more intensive land use on CLI land classes 3-4. This has ramifications which will impact on both input use and product growth during 1980-2030. (See Section 6.2.4 to 6.2.6. following).

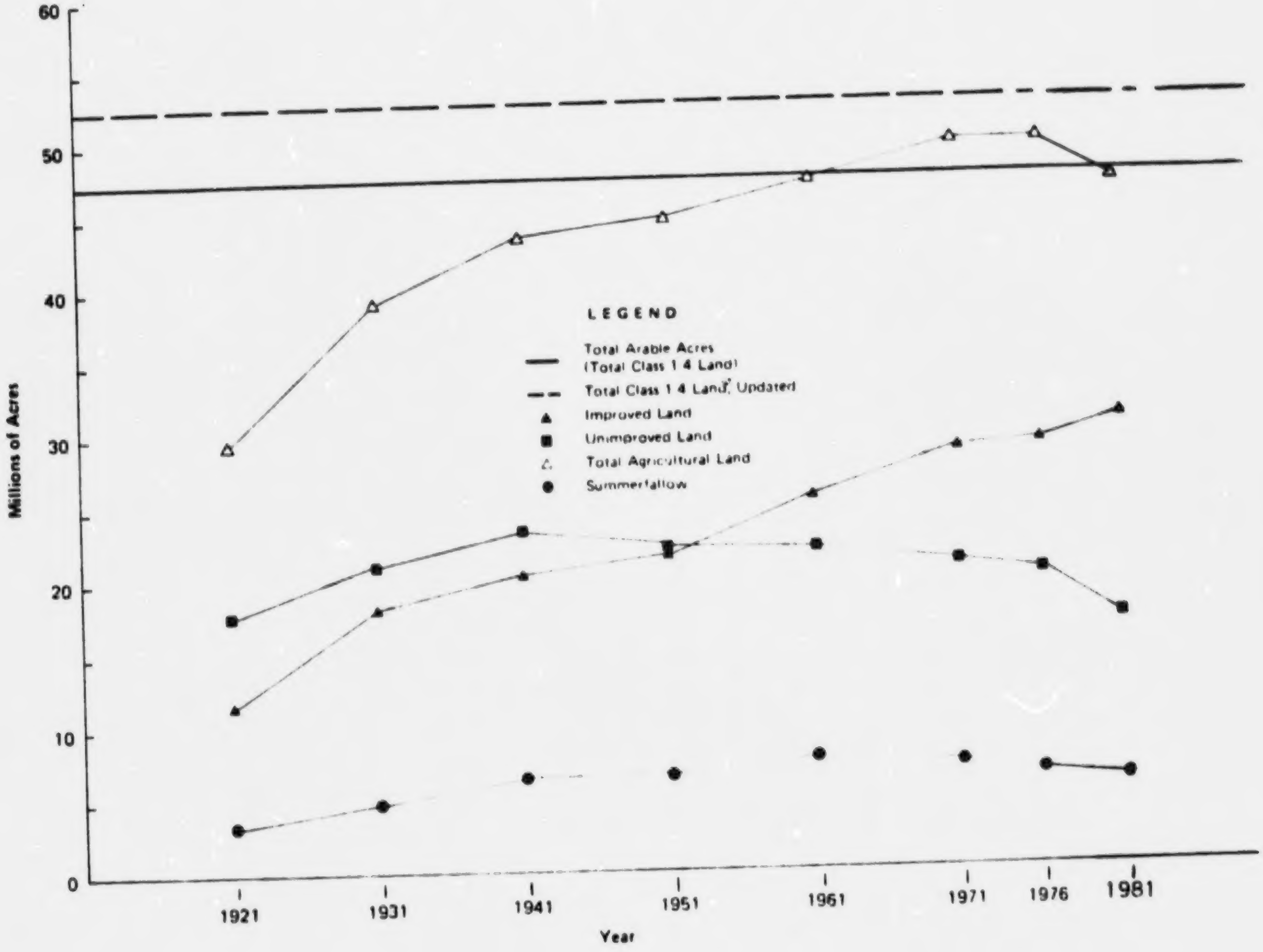
To further develop our basic agricultural land use scenario, it was also assumed that the summerfallow acreage would (according to market conditions) contract rather substantially

---

[1] Bracketed estimates tabulated in acres.

Figure 6.3

ACREAGE OF IMPROVED, UNIMPROVED AND TOTAL AGRICULTURAL LAND, COMPARED TO TOTAL ARABLE ACRES, ALBERTA, 1921-1981



Source: P.S. Thompson, **The Agricultural Land Base in Alberta,** ECA, Edmonton, 1981, p.66. Updated by utilizing the **Census of Agriculture,** 1981.

- a trend which once again has implications for future resource use: (million hectares)

	Pessimistic	Optimistic
1981 (actual)	5.4 (13.3)[1]	
1990	5.0 (12.4)	4.9 (12.1)
2000	4.6 (11.4)	4.4 (10.9)
2010	4.2 (10.4)	3.9 (9.6)
2020	3.8 (9.4)	3.4 (8.4)
2030	3.4 (8.4)	2.9 (7.2)

The projections are also generally consistent with existing studies on expected summerfallow practices. [2]

Summary projections of agricultural land use during 1980-2030 are provided in Appendix D, Table D.2.

6.2.3 Soil Degradation

Given that there has been and continues to be an acknowledged rate of soil "mining" through Alberta's brief agricultural history (see Figures 6.4 and 6.5) the rate and magnitude of past degradation trends has been difficult to access. The future is actually less obscure: as we slowly approach a critical minimum "natural" fertility level, it will become increasingly important for the agricultural industry to augment soil fertility levels simply to avoid *short-term* soil degradation and measurable on-farm financial losses.

This is the basis for our long-term projections in Section 6.4. following, given projected prices and costs, and assuming existing public policies remain intact:[3]

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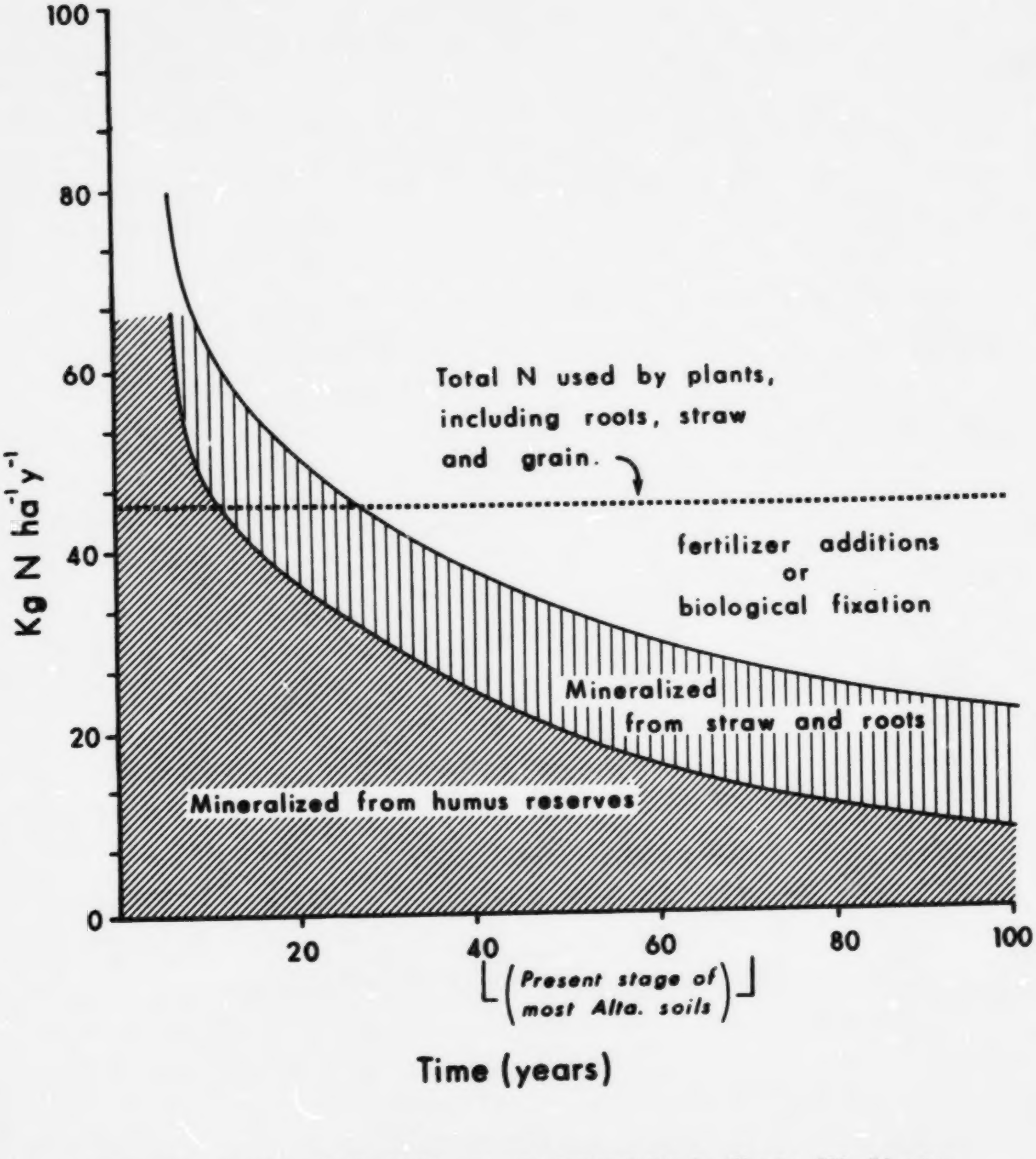
[1] Bracketed estimates tabulated in acres.

[2] Marv Anderson & Associates, **Factors Affecting Summerfallow Acreage in Alberta,** ECA, Edmonton, 1980.

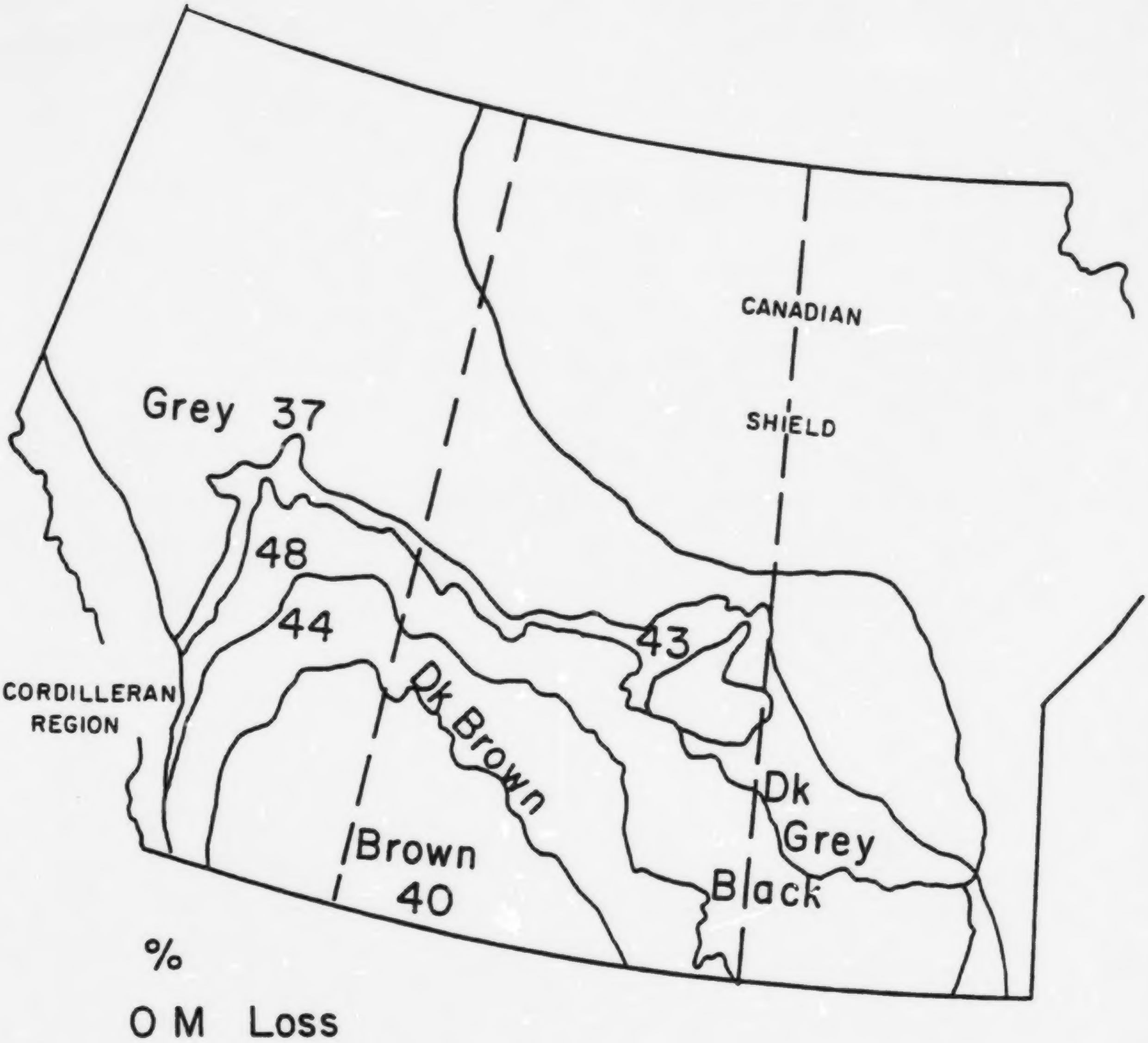
[3] For simplicity, the projected costs of soil acidification (via excess chemical fertilizer use, etc.) are not explicitly considered herein. The margin of error in the salinity and erosion cost projections probably exceed comparable soil acidification cost estimates.

Figure 6.4
PROJECTED TRENDS IN NITROGEN SUPPLY TO CROPS FOR "AVERAGE" ALBERTA CONDITIONS



Source: W.B. McGill, Soil Fertility and Land Productivity in Alberta, ECA, Edmonton, July, 1982, p.82.

Figure 6.5
SOIL ORGANIC MATTER LOSSES FROM THE A HORIZONS OF SOILS IN THE VARIOUS SOIL ZONES OF THE CANADIAN PRAIRIES


CANADIAN
SHIELD
Grey 37
48
44
43
CORDILLERAN REGION
Dk Brown
Dk Grey
Brown 40
Black
%
O M Loss

Source: W.B. McGill, et. al., **Soil Organic Matter Losses in Agricultural Land: Our Disappearing Heritage,** Proceedings of the Alberta Soil Science Workshop, Edmonton, 1981, p.10.

- The saline area will still increase, averaging 5 percent per year.
- Erosion will still continue, affecting another 10 percent of the cultivated land area by 2030.
- Fertility regeneration will still be inadequate, at least until 2020, perhaps reaching a point of equilibrium by 2030.

6.2.4 Yield Increase

This study focuses on the relationship between research and total productivity trends in Alberta agriculture: To what extent has research accelerated agricultural productivity trends in Alberta? And what productivity changes can we expect in the future, given our "track record" and anticipated technological breakthroughs in the future?

The partial productivity measures monitored by physical scientists generally refer to the *potential* yield increases which can be attributed to, say, a new barley variety or a new management practice, ignoring associated resource costs.

A total productivity analysis takes these two steps further: first, potential yield increases are translated into actual (applied) yield increases, and, second, the resource costs which are generally associated with yield increases are also tabulated as an offsetting cost.

Realized crop yield increases during 1930-1980 have been provided earlier (See Section III, Table 3.2).

Estimates suggest that a weighted average annual increase of about 2.5 percent per year has been typical of the crops sector. In the livestock sector, partial productivity measures are even more imprecise; but in this case an average annual yield increase of perhaps 0.5 percent per year probably characterized the industry during 1930-1980.

All existing partial productivity estimates are admittedly very imprecise. But what is even more obscure are the *sources* of this growth. During 1930-80 *perhaps* the following average annual changes in yields have been typical (%/year)[1].

Sources of Growth	Crops	Livestock	AVERAGE
Biological/Genetic	.54	.25	0.40
Chemical	1.00	.25	1.1
Mechanical	.50		
Management/Other	.46		
TOTAL	2.50%	0.50%	1.50%

But the crucial question is this: Can these rates be maintained during 1980-2030? Or will they increase? Decrease?

From the information summarized in Section VI and elsewhere we suggest that it is highly unlikely that historical yield increases can be extrapolated into the future, if we depend solely on our existing research capability ("research staff" and expenditures).

- The Agricultural research establishment in Western Canada is relatively small (reflecting Canada R & D expenditure patterns), traditional and diverse.
- Perhaps 40-50 percent of existing research is maintenance research (to avoid *absolute* yield declines)

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[1] This is one area where additional research is highly recommended. It would really help establish research priorities.

- There is very little research being conducted which could likely be translated into very large *major* potential gains for Alberta agriculture, e.g. cereal nitrification, nutritional drought-resistant forages for the Brown and Dark Brown soil zones, major (30-40%) increases in the genetic potential of both crops and livestock, frost-resistant crops, or winter grains for the central-north.

Further, there are at least two other major considerations which enter into this equation: (1) agricultural expansion on to "inferior" lands, and (2) changes in the quality of the existing land base over time.

The existing information available regarding (1) is well-documented.[1] (Table 6.1). Our own analysis generally supports this prior research: bringing more "inferior" agricultural land into production will, *ceteris paribus* depress *average* yields. The difference between barley yields on Class 4 land (versus Class 3 land), *ceteris paribus* is probably about 25 percent.[2] (See Figure 6.6).

In addition, continued soil degradation (even assuming a declining rate of *growth* - see subsection 6.2.3 above) will tend to depress future yield projections even more.

In short, the basic productivity scenario constructed in Section 6.4 following anticipates future realized yield increases of only 1 percent per annum during 1980-2030. Even with "major" breakthroughs (especially over 50 years), this is still considered a reasonable expectation; a good 50-year average if existing public policies remain intact.

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[1] See especially: P.S. Thompson, **The Agricultural Land Base in Alberta**, ECA, Edmonton, August 1981.

[2] Based on weighted CLI indices for each Census Division. Details available from the author upon request.

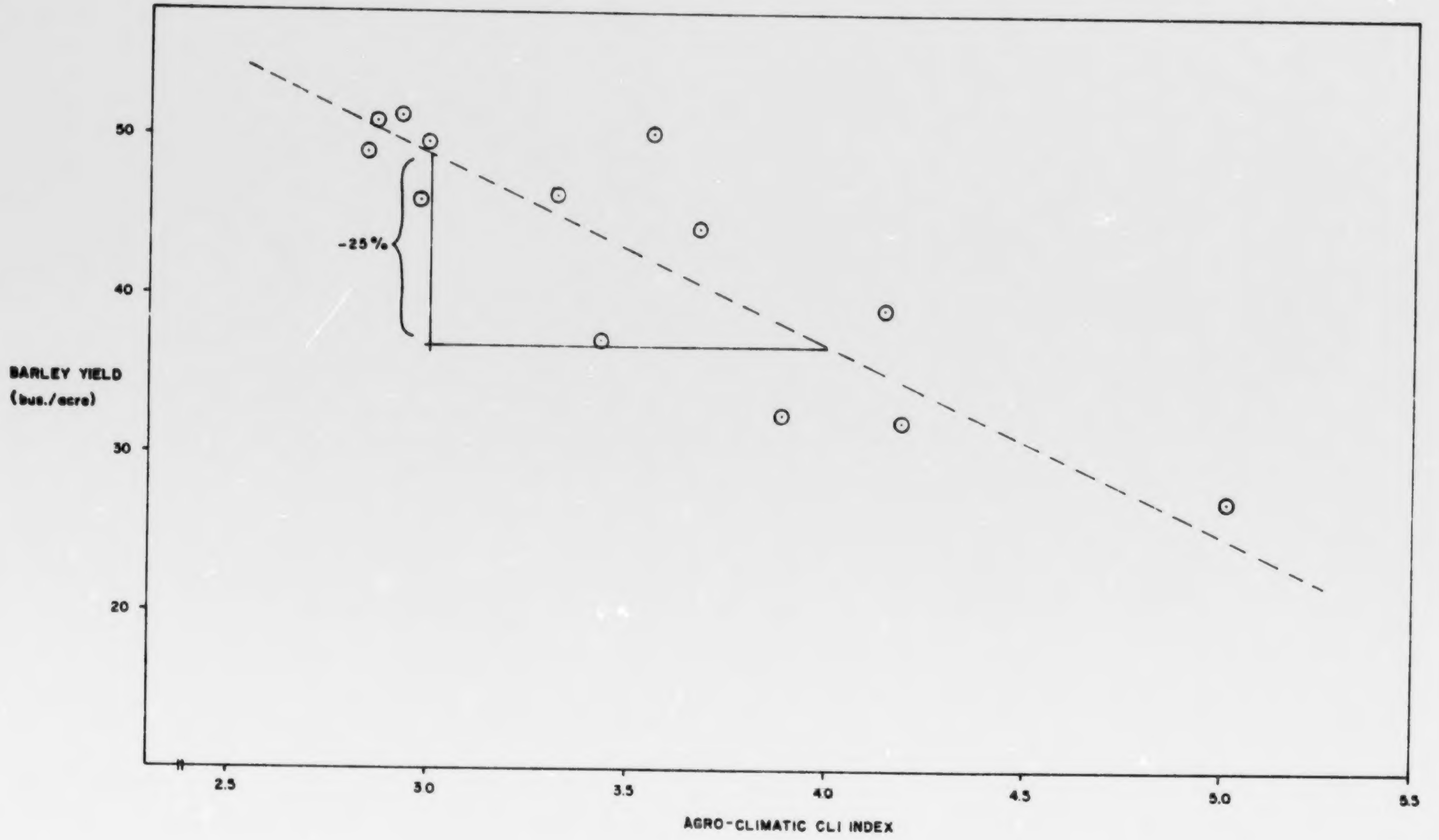
Table 6.1
COMPARATIVE YIELD INDICES FOR CLI CLASSES 1 TO 4

Location	Yield Indexes for each CLI Class				Comments	Reference
	CLI 1	CLI 2	CLI 3	CLI 4		
Canada	1.00	0.80	0.64	0.49	Yields of general field crops grown under good management practices; index relates classes 2, 3, and 4 to class 1	Bentley (1978a); Alberta Agriculture (n.d.a)
Canada	100 ha (247 ac.)	-	143 ha (353 ac.)	233 ha (576 ac.)	Straight productive comparison: number of hectares needed to replace the production of 100 ha of class 1 land	Agricultural Institute of Canada (1975)
Prairie Provinces	1.00	0.85	0.70	0.50	Index relates classes 2, 3, and 4 to class 1	Shields and Ferguson (1975)
Alberta						
Wheat (index)	1.00	0.83	0.67	0.50	Index relates classes 2, 3, and 4 to class 1	D. Macpherson (District Agriculturalist, Dept. Agric. Calgary, pers. comm. In CRPC 1977)
Wheat (bu./ac.)	25-30	20-25	15-20	< 15 or forage hay		
Alberta					Indexes calculated separately for classes 2H 2C, and 3H 3C. Each index relates northern and central Alberta to southern Alberta for each of wheat and barley	Bentley (1978a)
Wheat						
North	-	63	43	-		
Central	-	73	62	-		
South	-	100	100	-		
Barley						
North	-	62	44	-		
Central	-	72	71	-		
South	-	100	100	-		
Red Deer Area	1.00	0.80 ± 0.03	0.64 ± 0.04	0.50 ± 0.05	Based on yields for barley, oats and wheat, index relates classes 2, 3, and 4 to class 1	Tom Peters (Department Agriculture Edmonton, pers. comm. In RDRPC 1978)

Source: P.S. Thompson, **The Agricultural Land Base in Alberta,** ECA, Edmonton, August, 1981, p.20.

Figure 6.6

COMPARATIVE YIELDS ON DIFFERENT CLI CLASSES, ALBERTA



6.2.5 Input Projections

All major real cash input projections for agriculture are each dependent on two basic variables: (1) real future prices, and (2) the physical quantities required. Particular attention was given to four inputs: fuel, chemical fertilizer, chemicals (pesticides and herbicides), and machinery.

Projecting future chemical fertilizer requirements (or an equivalent substitute) proved to be particularly cantankerous because so many variables (other than relative prices and technology) enter into the equation:

(1) The changing land base (with expansion on to "inferior" lands)

(2) The projected decline in the acreage in summerfallow

(3) The growing demand for soil fertility regeneration

(4) Added fertilizer requirements to accommodate the projected yield increases during 1980-2030.

The first change is especially difficult to predict because existing secondary data does not make it abundantly clear how production costs are affected by soil quality. Nor is our own analysis very conclusive, as suggested in accompanying Figure 6.7.[1] However, a joint interpretation of Figures 6.6 and 6.7 might suggest that even though yields could drop 25 percent on inferior lands, variable costs of production only decline by about 10 percent.[2]

The assumptions ultimately built into the fertilizer use projections (aside from the simple area expansion) include:

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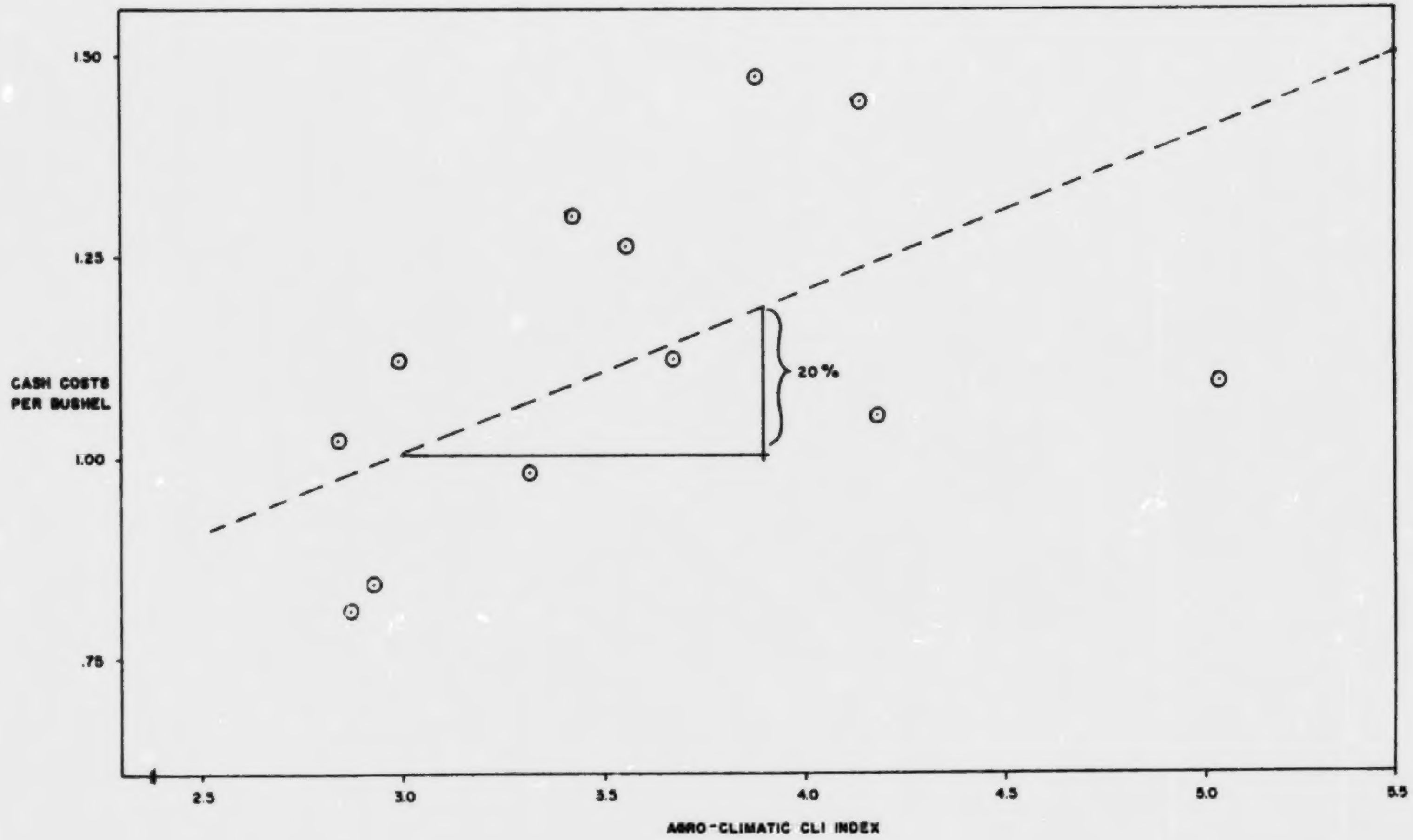
[1] Once again, this is based on weighted CLI indices for each Census Division. Details are available from the author upon request.

[2] At least this would be consistent with the proposition that the best land is the "cheapest" land.

Figure 6-7

RELATIVE COSTS OF PRODUCTION FOR CROPS, FOR AGRO-CLIMATIC ZONES IN ALBERTA



- fertilizer use on new lands will equal 90% of fertilizer use on old lands
- to rejuvenate existing land and substitute for less summerfallow, fertilizer use must increase by an additional 20% per decade (1980=basic)
- fertilizer use will increase by a further 1/2 percent per annum to facilitate simultaneous yield increases

The resulting fertilizer use projections suggest relatively high growth requirements (Appendix D.3).[1] The accompanying input projections for fuel, chemicals, and machinery (for Series A following) are also provided in Appendix Table D.3. In making these latter projections (based solely on projected cultivated area), the fuel consumption projections were adjusted downward by 5%/decade to account for expected future improvements in fuel efficiency levels.

6.2.6 Output Projections

The resulting output projections are simply the product of three variables detailed in the preceding:

Price - Section 6.2.1
Area - Section 6.2.2
Yields - Section 6.2.4

The output indices for the base projections used in Section 6.4 are: (1980=100)

	Pessimistic	Optimistic
1980	100	100
1990	124	139
2000	152	189
2010	186	253
2020	225	330
2030	271	423

---

[1] These chemical fertilizer cost projections should really be interpreted as a **shadow price** for any kind of soil nutrient re-generation, regardless of the precise technology employed. This would include the rotation of forages, manure, etc.. Thus, this scenario does not necessarily imply, for example, that additional soil acidification costs (because of excess chemical fertilizer use) will be incurred.

6.3 PRODUCTION SCENARIOS

Though many gains in production and productivity growth in the past are attributable to research efforts, gains in knowledge have not necessarily been transferred completely into tangible output or efficiency gains. Because of adoption rates, time lags in awareness of new techniques, improper implementation of new technology or market imperfections past changes are not incorporated instantaneously into practice. Such impediments to adoption have meant that gaps exist between laboratory results and results obtained in actual field use of new innovations or technologies.

While farmers may obtain early information on the productivity of new techniques, this new knowledge is first viewed with healthy scepticism. The information provides only a rough basis for formulating anticipations regarding improvements in yield or output which might be expected once adopted. Until farmers have obtained personal experience with the new technology they are understandably hesitant to commit financial resources where perceived risks of adoption are high. Because experiments ordinarily refer to highly selected or perhaps "unrepresentative" plots of land or groups of animals, farmers may wish to see how neighbors fare before they acquire new methods themselves. Inferences from small "unrepresentative" trials applied to entire species of animals or all soil areas may be viewed with suspicion. Thus, many farmers may discount the physical scientists' predictions or claims because of the uncertainty attached; they adopt a "wait-and-see" attitude before they adopt the technique. As other farmers adopt the technique, more results present themselves to potential adopters and a more realistic picture is presented on which to base a decision to implement the improvement. As continued acceptance spreads the use of a new technique or an innovation, a wider range of experience permits gains to be made in the actual results relative to the original claims made by scientists at the time the improvement was introduced.

The preceding characterizes the adoption process in general. As the farm community gains familiarity with new techniques or cultural practices, production performance with the new knowledge is likely to improve, approaching the experimental rates achieved by research scientists. Such conditions can be said to characterize the current situation in Alberta agriculture. That is, given existing levels of technology, considerable potential for further increases in production are entirely possible as farmers adopt and improve their skills in applying *known techniques and information.*

Irrigation

The development of irrigation in Southern Alberta provides a good example of this adoption lag and the existence of a "residual output" that may be practically possible to capture. Since 1974 cropped acreage under irrigation has increased from 620,000 acres to over 850,000 acres in 1981.[1] There remain approximately 250,000 irrigable acres in the irrigation districts which these figures represent and a potential irrigable acreage estimated at 2M acres for the province. [2]

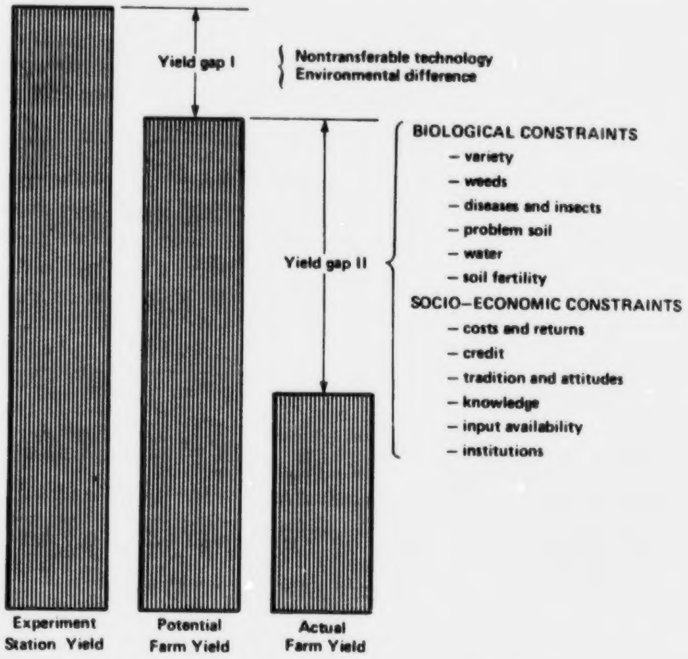
Over time the management and technological levels that have evolved within irrigated agriculture suggest three distinct yield levels as outlined in Figure 6.8 below.

---

[1] Alberta Agriculture, **Agriculture Statistics Yearbook 1981**, Statistics Branch, Agdex 853-10, Edmonton, 1982.

[2] Thompson, Peggy, **The Agricultural Land Base in Alberta**, Environment Council of Alberta, Edmonton, August, 1981.

Figure 6.8
CONSTRAINTS TO IRRIGATED CROP YIELDS



Source: K.A. Gomez, "On-farm Assessment of Yield Constraints: Methodological Problems," **Constraints to High Yields on Asian Farms: An Interim Report,** International Rice Research Institute, Manila, 1978, p.2.

Biological and socio-economic constraints constitute factors which place the most severe pressure on farm managers in terms of realized gains in production from the types of system employed. It is the management factor which is stressed in terms of closing the gap between actual farm yields and experimental station yields for irrigated crops. To quote:

> Regardless of the system chosen, it cannot be overstated how important good management is. Management is the key as money has been made, and lost, with almost all types of systems on all types of crops.[1]

---

[1] Alberta Agriculture/Irrigation Division, **Alberta Irrigation Management Course,** Lethbridge, Fall 1981, Chapter V, p. 21.

For the irrigation districts in southern Alberta the distinction between actual versus potential versus the experimental crop yields has been estimated as follows·[1]

Crop	Actual Farm Yields[a] (minimum)	Potential Yields (expected)	Experimental Station Yields (maximum)
Spring Wheat	2613	3483	4352
Oats	2658	3512	4439
Barley	3940	5397	6580
Rye	2016	2707	3339
Flax	1260	1699	2104
Rapeseed	1680	2519	3470

[a] Yields are in kilograms per hectare.

The yield increases which are possible based solely on improved knowledge and management of irrigated agriculture (economics permitting) can be expressed in terms of gains over existing average yields:

	Potential	Experimental
Wheat	+33%	+67%
Oats	+33%	+67%
Barley	+37%	+75%
Rye	+34%	+66%
Flax	+35%	+65%
Rapeseed	+50%	+107%

Since irrigation represents a small proportion of all agricultural land in Alberta, the gains, though significant in themselves, represent a relatively small addition to total crop production. The point being made, however, is that these gaps are *representative* of management practices inherent in the adoption or technology transfer process. In this sense, the yield gap for irrigated crops might also be applied to dryland crops in order to measure the potential gains which are still possible with "on-the-shelf" technologies, economics permitting.

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[1] **Basic Source:** As calculated from numerous sources in: Marv Anderson and Associates, Ltd., **Blood Indian Irrigation Feasibility Study: Agronomy Study Component**, Willingdon, Alberta, November, 1981, pp. 57-57 and Appendix B.

Dryland Crops

Applying the foregoing potential and experimental yield possibilities to dryland grain acreages gives an approximation of foreseeable increases in output levels to Alberta agriculture. Table 6.2 presents five-year average area, yield and production data for the six major grains grown in the province. Taking the five-year averages as representative of actual yields, the base production levels may be compared to the potential and experimentally possible rates. Here, the YIELD1 and YIELD2 scenarios correspond to potential and experimental conditions respectively.

Table 6.2
ACTUAL, POTENTIAL AND EXPERIMENTAL PRODUCTION SCENARIOS DRYLAND GRAINS, ALBERTA

CROP	AREA[a]	YIELD[b]	PRODN[c]	YIELD1	PRODN1	YIELD2	PRODN2
Wheat	2227	2020	4556	2687	5984	3374	7514
Oats	571	2233	1271	2969	1695	3730	2130
Barley	2158	2534	5482	3473	7494	4436	9573
Rye	101	1993	207	2670	270	3310	334
Flax	58	1176	68	1588	92	1939	112
Rapeseed	947	1191	1102	1786	1691	2465	2334
TOTAL	6062		12686		17226		21997

[a] Area in hectares (,000).

[b] Yield in kilograms/hectare.

[c] Production in ,000 tonnes.

Source: Alberta Agriculture, Agricultural Statistics Yearbook, op. cit.

Applying the above yield increments to the five-year average yield values results in gains in total production of 36% with potential yields (17,226,000 tonnes vs. 12,686,000) and 73% with experimental levels (21,997,000 tonnes vs. 12,686,000).

Though these estimates are pure conjecture and pay no heed to marketing problems or related production costs in order to achieve potential gains, they are *technically possible.* In a relative sense, they are a useful measure as to what production possibilities do exist under given managerial and technological conditions.

6.4 ALTERNATIVE PRODUCTIVITY SCENARIOS

6.4.1 Introduction

Virtually all of the underlying projections implicit in Scenario A following have been detailed in Section 6.2 above.[1] This Scenario essentially assumes that only the existing level of support for agricultural research and soil/water conservation programs will be realized during the 1980-2030 period. It is a "status quo" scenario under two price/cost regimes.

Scenario B, C and D determine how sensitive the total productivity growth rates (derived in Scenario A) are if agricultural research and/or soil/water conservation programs are accelerated. Each is discussed in turn.

6.4.2 Scenario A - Status Quo

The status quo scenario at least *suggests* that extrapolating the past into the future will probably result in a *declining* rate of growth in total factor productivity in Alberta agriculture (Table 6.3).

Table 6.3

SCENARIO A: PROJECTED PRODUCTIVITY INDICES FOR ALBERTA AGRICULTURE (1971=100)

	Productivity Indices			Growth Rates (%/year)	
Year	Pessimistic	Optimistic	Period	Pessimistic	Optimistic
1980	.94	.94	1980-1990	1.26	2.19
1990	1.06	1.16	1990-2000	1.14	1.84
2000	1.19	1.40	2000-2010	1.03	1.47
2010	1.32	1.61	2010-2020	.78	1.04
2020	1.42	1.79	2020-2030	.55	.69
2030	1.50	1.92			
			1980-2030	.95	1.45

---

[1] One difference in Scenarios A-D is that it is here assumed that the total agricultural land area affected by salinity in 1980 was about 400,000 ha. (versus 300,000 ha., as assumed in Section 6 and Appendix C, Table C.3(a)). If not justified, this difference may slightly bias downward all productivity estimates (by, say, .01) in Tables 6.3-6.6 following.

Depending on the price/cost regime in effect, the average rate of growth in total factor productivity in Alberta agriculture could drop to about *one-half* of the average rate of growth characteristic of the pre-1980 period.

6.4.3 Scenario B - More Ag. Research

Scenario B is called the "research augmentation scenario", completely ignoring "major breakthroughs".

The Scenario postulates that an increase in Alberta-Canada research expenditures of some $70 M/year (in 1981 dollars) should very easily generate an increase in crop and livestock yields of *1/4 of one percent* per annum. (This is just a 25% increase in the growth of yields vis-à-vis Scenario A).

Assuming there is a 10-year lag between research expenditures and actual productivity increases (6-10 years is historically accurate), the simulation then determines how this strategy impacts on the resulting total productivity projections for Alberta agriculture. The results are summarized in Table 6.4.

Table 6.4
SCENARIO B: PROJECTED PRODUCTIVITY INDICES FOR ALBERTA AGRICULTURE (1971=100)

	Productivity Indices			Growth Rates (%/year)	
Year	Pessimistic	Optimistic	Period	Pessimistic	Optimistic
1980	.94	.94	1980-1990	1.05	1.99
1990	1.04	1.14	1990-2000	1.31	2.06
2000	1.18	1.40	2000-2010	1.24	1.61
2010	1.34	1.64	2010-2020	.97	1.26
2020	1.47	1.86	2020-2030	.72	.90
2030	1.58	2.03			
			1980-2030	1.06	1.56

The difference between Scenario A and Scenario B is obvious. Under Scenario B, a 10-20 percent increase in the *rate* of productivity growth is quite possible. And this completely ignores the fact that greater agriculture research expenditures would undoubtedly increase the probability of a major research breakthrough - thus augmenting the rate of growth even more. Clearly, the payoff to research (particularly research specific to Alberta) is very high and yet it remains a grossly undervalued resource.[1]

6.4.4 Scenario C - More Soil Conservation Programs

It is not the purpose of this report to investigate the ways and means of becoming more "conservation-minded" in Alberta. In any event, there is a very limited secondary data base from which to draw. The quantitative benefits which would actually accrue to Alberta agriculture (and society in general) if more public support for conservation programs was actually forthcoming are not well-known.

Some comparative statistics are available, however, regarding expenditures on soil and water conservation in neighboring states and provinces (Figures 6.9-6.10). An Alberta-Montana comparison is particularly illustrative: ($/ha.)[2]

	ALBERTA	MONTANA
Prov./State	0.50	1.80
Federal	0.30	3.00
TOTAL/HA.	$ 0.80	$ 4.80

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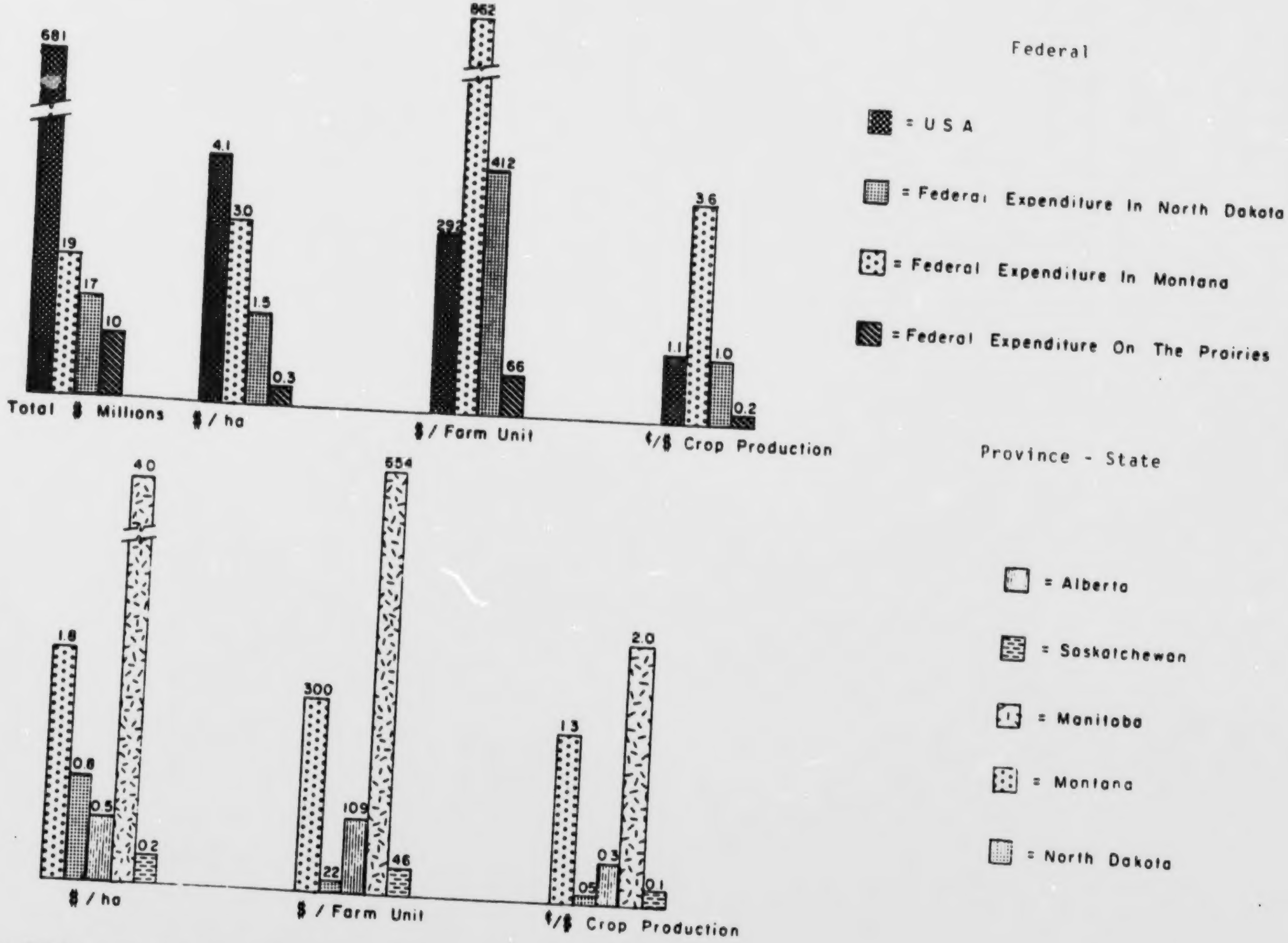
[1] See Section II. Also see G. Brinkman, **op. cit.**

[2] Calculations based upon the **improved** agricultural land area, i.e. crops + improved pasture + other improved land.

Figure 6.9

COMPARATIVE FEDERAL, PROVINCIAL AND STATE EXPENDITURES
ON SOIL AND WATER CONSERVATION 1979



Source: DRIE/PFRA, Land Degradation and Soil Conservation Issues, Regina, November 1982, pp. 18 19.

Figure 6.10

Alberta-Montana Land Use Patterns, 1980

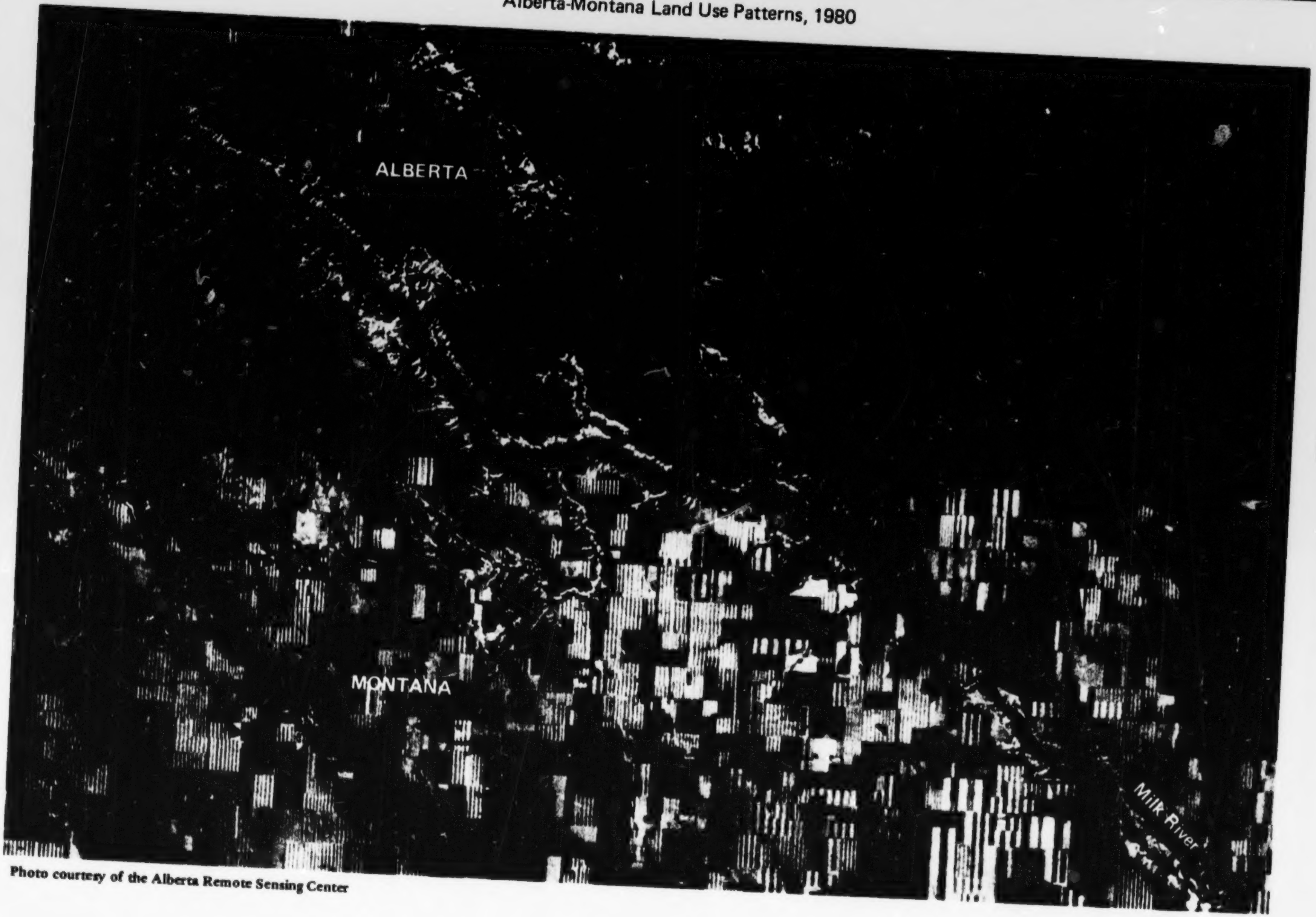

ALBERTA
MONTANA
Milk River

Photo courtesy of the Alberta Remote Sensing Center

The vastly different expenditure levels on soil and water conservation in these neighboring lands is readily apparent.

The Landsat picture (Figure 6.10) reveals a marked difference in land use intensity between Montana and Alberta crop lands. The marked distinction enables the viewer to draw a line between the neighboring states and provinces tracing the international border. The picture partially indicates how a change in economic conditions, social priorities and attitudes to soil conservation may impact on agricultural production patterns relative to the land base available.

Thus, Scenario C asks: what if expenditure levels in Alberta were similar to those in Montana? To what extent might this augment long-term agricultural productivity trends in Alberta?

To simulate this situation, two basic changes to Scenario A have been made:

(i) Instead of current expenditures of (say) $10M/annum on soil and water conservation programs in Alberta, it is assumed that this is increased to $60M/year -- an increase of $50M/year, while, conversely,

(ii) Total land costs in Scenario A are adjusted downward to reflect the anticipated social benefits of greater conservation expenditures,[1] namely:
  - the rate of *growth* in saline areas is moderated to one half the rate in Scenario A, i.e. 2.5%/year versus 5%/year.[2]
  - the rate of growth in the agricultural area affected by wind and water erosion is also halved, i.e. 5% versus 10% more land during 1980-2030.

---

[1] Some market-determined "conservation" measures are already assumed in Scenario A. E.g. fertility augmentation and reduction in the acreage in summerfallow. See the text and related Appendices for details.

[2] Recall, however, that some sources claim the present rate of growth is 10%/year.

And once again, the simulation constructed suggests that these public programs also have a very positive impact on future productivity levels in Alberta agriculture (Table 6.5).

Table 6.5

SCENARIO C: PROJECTED PRODUCTIVITY INDICES FOR ALBERTA AGRICULTURE (1971=100)

Year	Productivity Indices Pessimistic	 Optimistic	Period	Growth Rates (%/Yr) Pessimistic	 Optimistic
1980	.94	.94	1980-1990	1.17	2.11
1990	1.05	1.15	1990-2000	1.26	1.97
2000	1.19	1.40	2000-2010	1.22	1.69
2010	1.34	1.66	2010-2020	1.13	1.41
2020	1.50	1.90	2020-2030	1.13	1.28
2030	1.68	2.16			
			1980-2030	1.18	1.69

In this case, rates of growth in productivity levels in Alberta agriculture during 1980-2030 would likely be augmented 15-25 percent.

6.4.5 Scenario D - More Research and Conservation Programs

The final scenario considered simply asks the question: what if Scenario B and C above were combined? The results are predictable (Table 6.6).

Table 6.6

SCENARIO D: PROJECTED PRODUCTIVITY INDICES FOR ALBERTA AGRICULTURE (1971=100)

	Productivity Indices			Growth Rates	
Year	Pessimistic	Optimistic	Period	Pessimistic	Optimistic
1980	.94	.94	1980-1990	.96	1.91
1990	1.03	1.13	1990-2000	1.47	2.25
2000	1.19	1.41	2000-2010	1.50	1.86
2010	1.38	1.70	2010-2020	1.37	1.68
2020	1.58	2.01	2020-2030	1.47	1.63
2030	1.83	2.36			
			1980-2030	1.35	1.87

With both of these programs in place, the growth rate in productivity levels in Alberta agriculture could well be augmented 30-40 percent, perhaps more.

This is at least illustrative of how sensitive the total productivity index is to more public support for agriculture. Repeatedly, the various simulations also suggest that this public support is even more critical when profit margins in agriculture are relatively low (i.e. the pessimistic case). If this additional public support is not forthcoming, our projections further suggest that the rate of growth in the productivity of Alberta agriculture during 1980-2030 will most likely lag behind the productivity gains experienced during 1930-80. And this diminishing growth rate could well become more acute over time.

SECTION VII
SUMMARY

7.1 SUMMARY

Alberta-based research is generally supplemental to the vast national and international research complex which is already in place and largely determines the broad research priorities ultimately established in Alberta. Perhaps ninety-five percent of the basic technology employed on Alberta farms is imported from outside the province. Adaptive technology, however, largely comes from scientists in Alberta or other facilities on the Prairies.

Continued research is a necessary (although not sufficient) condition for future productivity gains in agriculture:

RESEARCH ⟶ TECHNOLOGY ⟶ PRODUCTIVITY

Historically, the rate of return to agricultural research has been relatively high, even considering the social-environmental costs incurred. Despite this, funding for on-going research in Alberta and elsewhere may continue to be undervalued by the public. This is generally the case when the demand for agricultural commodities is growing slowly and most gains are passed on to consumers in the form of lower prices.[1] The rising cost of the non-agricultural component in todays' "food basket" also disguises the real value of this benefit to the consumer.

The irrefutable link between research and the potential productivity gains in agriculture is also obscure because numerous factors determine if and when a farmer will actually adopt a technology which is in effect, already "on the shelf":

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[1] Nagy, J.G. and W.H. Furtan, **The Socio-Economic Costs and Returns from Rapeseed Breeding in Canada,** Dept. of Ag. Ec., U of S., Saskatoon, May 1977. The authors estimated that 50% of the returns to rapeseed research were passed on to consumers.

(1) Nature of the technical advance, i.e. output increasing or factor-saving (implications for relative factor returns).

(2) Appeal to farmer - satisfaction of perceived needs.

(3) Profitability.

(4) Compatibility with attitudes toward change.

(5) Simplicity/complexity of the advance.

(6) Availability - knowledge, materials and credit.

(7) Applicability - the advance facilitates immediate use and visible results or is more long run in nature.

(8) Cost - impose any explicit or hidden costs on those who adopt the change.

(9) Level of Risk - success in application assured.

(10) Education - knowledge and skill level of prospective users affects their desire to employ technological improvements.

(11) Communicability - results of employing the advance should be easily visible to all participants.

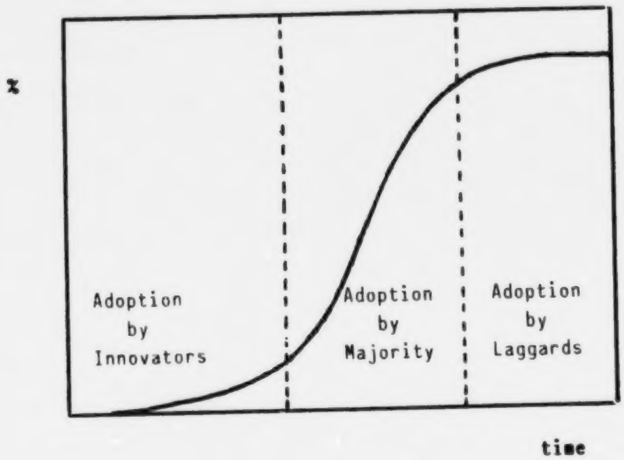
(12) Promotion - assistance, extension advice and advertising encourage trial of new knowledge or techniques.

(13) Current state of technology at the time the new technique is introduced.

(14) Relative factor prices of those resources currently employed in production activities at the time of new technique introduction.

(15) Structure - contract farming for canners or processors (e.g. sugar beets).

This gives rise to the familiar S-shaped curve:



Generally speaking, yield improvements have been responsible for about two-thirds of all crop production increases in Alberta during the last 50 years (see Table 3.1). And, in turn, these historical yield increases can be traced to the following: (%/year)[1]

Sources of Growth	Crops	Livestock	AVERAGE
Biological/Genetic	.54	.25	0.40
Chemical	1.00	.25	1.1
Mechanical	.50		
Management/Other	.46		
TOTAL	2.50%	0.50%	1.50%

Historically, genetic improvements (esp. for crops) have been overshadowed by chemical, mechanical and managerial improvements (Table 3.3). In any event, the resulting increase in farm labor productivity has been rather dramatic--about 428 percent during the 1946-81 period. These and other partial productivity measures are particularly useful in examining the trends in productivity in terms of a single input over time. But these measures can also be misleading.

---

[1] **Very approximate.** This is one area where additional research is highly recommended to help establish future research priorities.

The best single indicator of *efficient* economic growth in the agricultural sector is the total (or multi-) factor productivity index, a measure of *total agricultural output* relative to *total costs of production*. Annual rates of growth in total factor productivity in Alberta agriculture during 1930-80 have been estimated to be as follows:[1] (%/year)

1930-39	-2.49
1940-49	2.45
1950-59	4.02
1960-69	2.30
1970-80	.11
1930-80	2.04

These estimates are generally consistent with other very recent studies for all of Prairie agriculture.[2]

Although far from definitive, a set of consensus estimates may yet emerge--estimates which suggest that the rate of total factor productivity growth in agriculture may have actually peaked during the 1950's, declining thereafter. The available evidence at least gives some credibility to the proposition that productivity increases in agriculture may have reached a plateau. The reasons for this apparent decline in growth are much more obscure.

But what about the future? What production and productivity increases can be expected in Alberta agriculture during the next fifty years? From interviews with research scientists throughout the Prairies, a number of initial observations about the future can be made:

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[1] Base case. For further details, see Table 4.4.

[2] T.Islam and G.L.Brinkman and B.E.Prentice. For further details, see Table 4.1.

- No major breakthrough in agricultural research is expected before the turn of the century. Gains to be made will likely come in incremental steps.

- Researchers at the more northerly research facilities are very optimistic about the agricultural potential of the north. In one interview the challenge of northern agriculture now was likened to the challenge of agriculture in southern areas in the early 1900's.

- The research undertaken by those scientists interviewed is very much problem or goal oriented. With a few exceptions (e.g. plant and animal breeding, bio-control and soils research) research projects tended to be 5 years or less in duration with results to be expected within that time frame.

- Concern exists within the research establishment that without increases in research funding in the near future, important research projects may have to be curtailed or cancelled. While many acknowledged a need for greater staffing, few expected any increases within the next five years.

- In total, research scientists are generally optimistic about future productivity gains in agriculture. Of the forty-one scientists expressing an opinion about future productivity levels, thirty-one (76%) felt that productivity would increase in the forseeable future. Ten scientists (24%) felt that productivity levels would plateau as input costs continued to rise. None felt that productivity in agriculture would decline. At the same time, a number of perceived obstacles to future productivity increases in Alberta have been identified, as summarized in Table 7.1.

Table 7.1

PERCEIVED OBSTACLES TO FUTURE PRODUCTIVITY GROWTH IN AGRICULTURE

Obstacle	Ranking[a]				Composite Index[b]
	IV	III	II	I	
	(number of responses)				
Economic Conditions	10	9	3	1	74
Producer Adoption of Technology	1	–	4	4	16
Research Funding/ Staff	6	3	8	5	54
Deteriorating Resource Base	2	3	2	3	24
Inadequate Extension/ Consumer Education	–	1	1	2	7
Climate/Weather	3	5	1	2	31
Government Policies	1	1	4	6	21
Lack of Markets	2	2	2	2	20
Crop Storage	–	1	–	–	3
TOTAL RESPONSES	25	25	25	25	

[a] Rankings are presented in declining order of importance with IV indicating the greatest perceived obstacle and I indicating a lesser degree of importance.

[b] The composite index is derived by multiplying the number of responses for each ranking by the implied relative importance of each ranking.
e.g. economic conditions = 10 (4) + 9 (3) + 3 (2) + 1 (1) = 74

Source: Table 5.4.

Regarding projected production increases, our first extrapolation simply assumes 100 percent application of existing "on-the-shelf" technology.[1] In this case, dryland crop production could climb at least one-third and probably more. With existing experimental yields throughout the province, a production increase of two-thirds of current production is not impossible.

A second set of projections was also prepared by extrapolating agricultural output levels in conjunction with numerous other projections regarding future prices, technological change, institutional parameters, and implied resource implications (see Section VI). These output projections are equally optimistic: By 2030, total agricultural production might well expand 300-400 percent, i.e. 3 or 4 times present output levels.

In this context, it is assumed that a 25-55% increase in the improved agricultural land base during 1980-2030 is possible, consistent with rates of expansion during the last two decades. Perhaps this is *too* optimistic. But these future production estimates also assume a composite yield increase of only 1 percent per annum for this same period, a much lower rate than that actually achieved during 1930-1980. Perhaps this is too pessimistic. Other estimates would be equally speculative. The point which must be emphasized is simply this: the *potential* for future agricultural growth in Alberta agriculture is very considerable.[2] The more pertinent question is "At what cost?"

To partially answer this question, the annual average rate of growth in total factor productivity in Alberta agriculture was estimated for the period 1980-2030, as tabulated in Table 7.2. These calculations at least suggest that the total production increases envisioned (300-400

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[1] With the existing land base.

[2] Measured in terms of gross output.

Table 7.2

PROJECTED PRODUCTIVITY INDICES FOR ALBERTA AGRICULTURE (1971 = 100)[a]

Year	Productivity Indices		Period	Growth Rates (%/yr.)	
	A	D		A	D
1980	.94	.94	1980-1990	1.26	.96
1990	1.06	1.03	1990-2000	1.14	1.47
2000	1.19	1.19	2000-2010	1.03	1.50
2010	1.32	1.38	2010-2020	.78	1.37
2020	1.42	1.58	2020-2030	.55	1.47
2030	1.50	1.83			
			1980-2030	.95	1.35

[a] Scenario A = status quo; narrow margins. Scenario D = more research and soil conservation; narrow margins.

Source: Table 6.3 and Table 6.6 respectively.

percent over 50 years) should be possible without sacrificing economic efficiency. Even with a status quo scenario, the productivity index is expected to climb. At the same time however, it is unlikely that the *rate of growth* in productivity could be maintained with existing levels of public expenditure for research and soil conservation in the agricultural sector. Conversely if these public expenditures were augmented, it seems entirely possible to continually augment productivity such that a relatively constant rate of productivity growth could be achieved. This constant ("equilibrium") rate of growth is particularly desirable if it can be demonstrated that all alternative policy options could involve irreversible soil/water degradation.

These tentative findings are generally consistent with the conclusions reached in a similar study in the United States.[1] That study suggests that productivity increases of one percent per year (during the next 50 years) should be possible (in the U.S.) if adequate funding for agricultural research is forthcoming and favorable socio-economic-political conditions prevail.

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[1] Council for Ag. Science & Technology, **Preserving Agricultural Land: Issues and Policy Alternatives**, Report No. 90, Ames, Iowa, July 81, p.11.

7.2 FINAL COMMENTS

1. The forces which shape the agricultural industry in Alberta are largely external to the province. A competitive international market generally dictates how resources will be employed in the agricultural sector, particularly regarding land and water. This may involve some on-going social costs which are not tabulated in a conventional national accounting framework. Provincial policies should reflect an awareness of these costs.

2. With reference to (1), accountability must also be extended to the research establishment. Applied, short-term ("squeaky wheel") research to sustain the existing capabilities of Alberta agriculture appears to be conducted in a relatively efficient and effective manner. This is generally less true of longer-term, more basic research which might give future producers in Alberta a competitive advantage in the international market place. To be more effective, this should be further rationalized (priorized) and, thereafter, augmented very considerably.

3. One way to help ensure that the growth of Alberta agriculture is consistent with (1) and (2) above is to utilize a multi-factor productivity index approach. Despite the practical and methodological limitations inherent in this approach, it has a number of very unique characteristics:

- it explicitly identifies both the private benefits and costs of alternative growth scenarios
- it can explicitly consider the social costs which might also be incurred, e.g. soil degradation
- it is a convenient and easily understood benefit-cost framework which is frequently utilized by other analysts and disciplines

- it addresses the issues in terms of economic efficiency in an inter-generational context

The emphasis on efficiency (versus conventional "bigger is better" criteria) is particularly important if Alberta agriculture is to remain a truly renewable resource in the challenging years ahead.

4. During the course of this study, the information base proved to be particularly inadequate with respect to:

- the sources of growth regarding yields
- the payoff to agricultural research conducted in Alberta
- the relative costs of agricultural production in different agro-climatic regions of the province (crops and livestock)
- the extent and severity of on-going soil degradation

In these areas, additional studies are highly recommended.

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APPENDIX A

TERMS OF REFERENCE

Terms of Reference

Research and Agricultural Productivity in Alberta

The basic objective of the study is to identify:

(a) who (and where) is doing agricultural research applicable to Alberta;
(b) what the focus of this research is;
(c) what factors determine technological transfers to Alberta agriculture; and
(d) what the potential is for increased production (short-term (20 years) and long-term (50 years)) of crops and livestock in Alberta as a result of this research and these technological transfers.

This objective will be achieved through the following study components:

(a) **Technological Transfers to Alberta Agriculture** will provide a historical review of where applied research in Alberta has come from and how it has been transferred to on-farm use.
(b) A **Descriptive Analysis** will be provided to determine what factors have contributed to agricultural productivity increases in Alberta, with particular emphasis on identifying what the role of applied research has been.
(c) A discussion of **Historic Productivity Changes** will review estimates of total productivity changes in Alberta and determine: how Alberta agriculture has fared relative to Canada as a whole; how much confidence can be placed in earlier Canada–U.S. estimates of productivity changes in agriculture; and if historic growth rates are declining.
(d) **The Future Role of Alberta–Canada Research** will identify the who-what-where-when and why of current agricultural research programs (to involve extensive interviews with research personnel in Brooks, Lethbridge, Lacombe, Beaverlodge, Vegreville, Ft. Vermilion, Swift Current, Indian Head, Regina, Brandon, and Ottawa).
(e) **Alberta Projections, 2000–2030** will identify and project the future magnitude of the major variables influencing research, technological advances and adoption, and agricultural output. A number (approximately four) of alternative scenarios will be developed to identify the implications of variable changes for future agricultural productivity and resource use.
(f) **Summary, Critique and Issues** will summarize key findings, provide a critical analysis of current research and technological transfer processes, and identify questions and issues related to the study but beyond these terms of reference.

The study is intended to provide the ECA with an assessment of the opportunities for potential improvements in agricultural productivity resulting from research and technological advances.

APPENDIX B

BACKGROUND DATA

Figure B-1

REALIZED GENETIC YIELD INCREASES
VERSUS
ACTUAL YIELD INCREASES, WHEAT

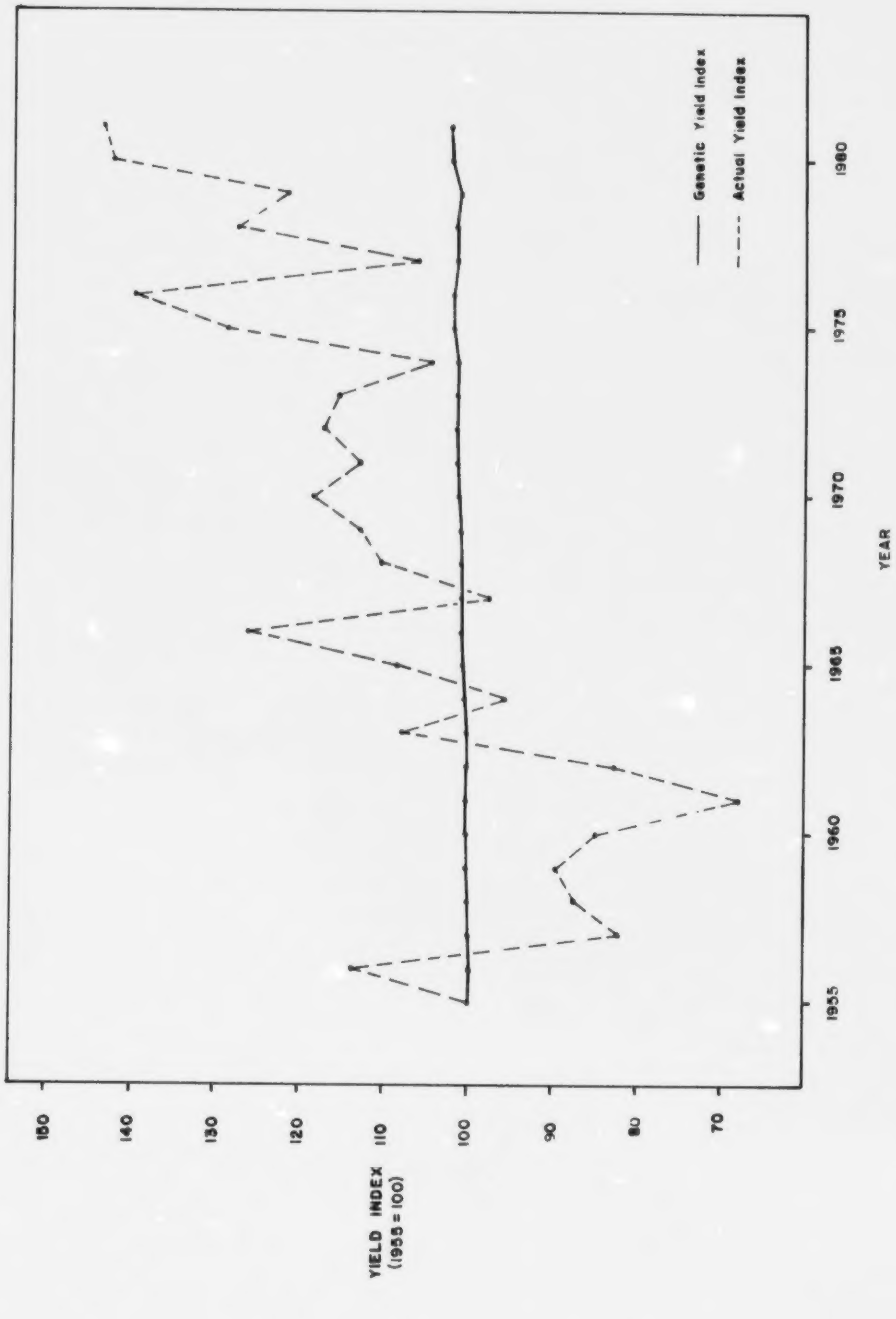

Figure B-2

REALIZED GENETIC YIELD INCREASES
VERSUS
ACTUAL YIELD INCREASES, BARLEY

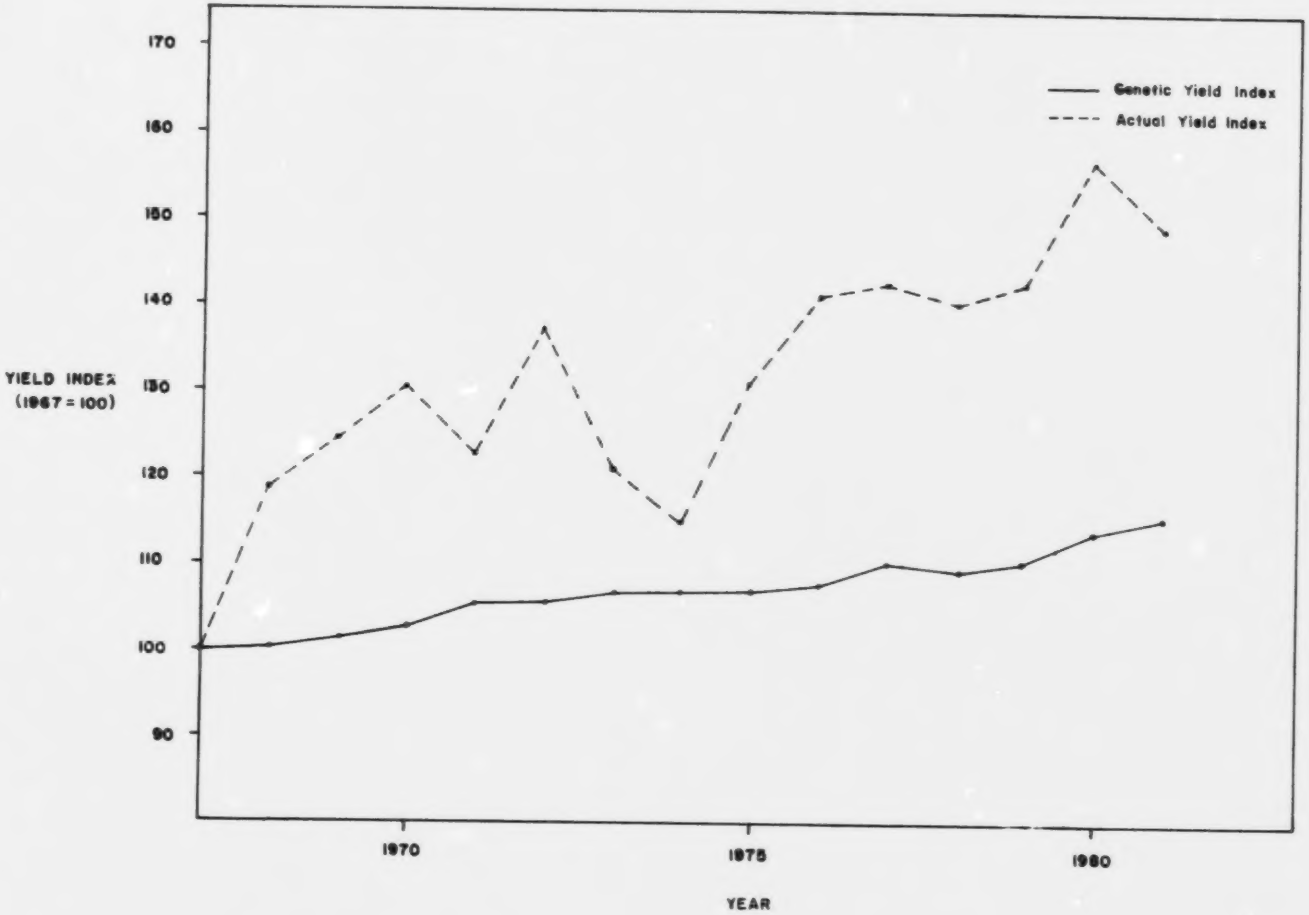

Figure B-3

REALIZED GENETIC YIELD INCREASES
VERSUS
ACTUAL YIELD INCREASES, CANOLA

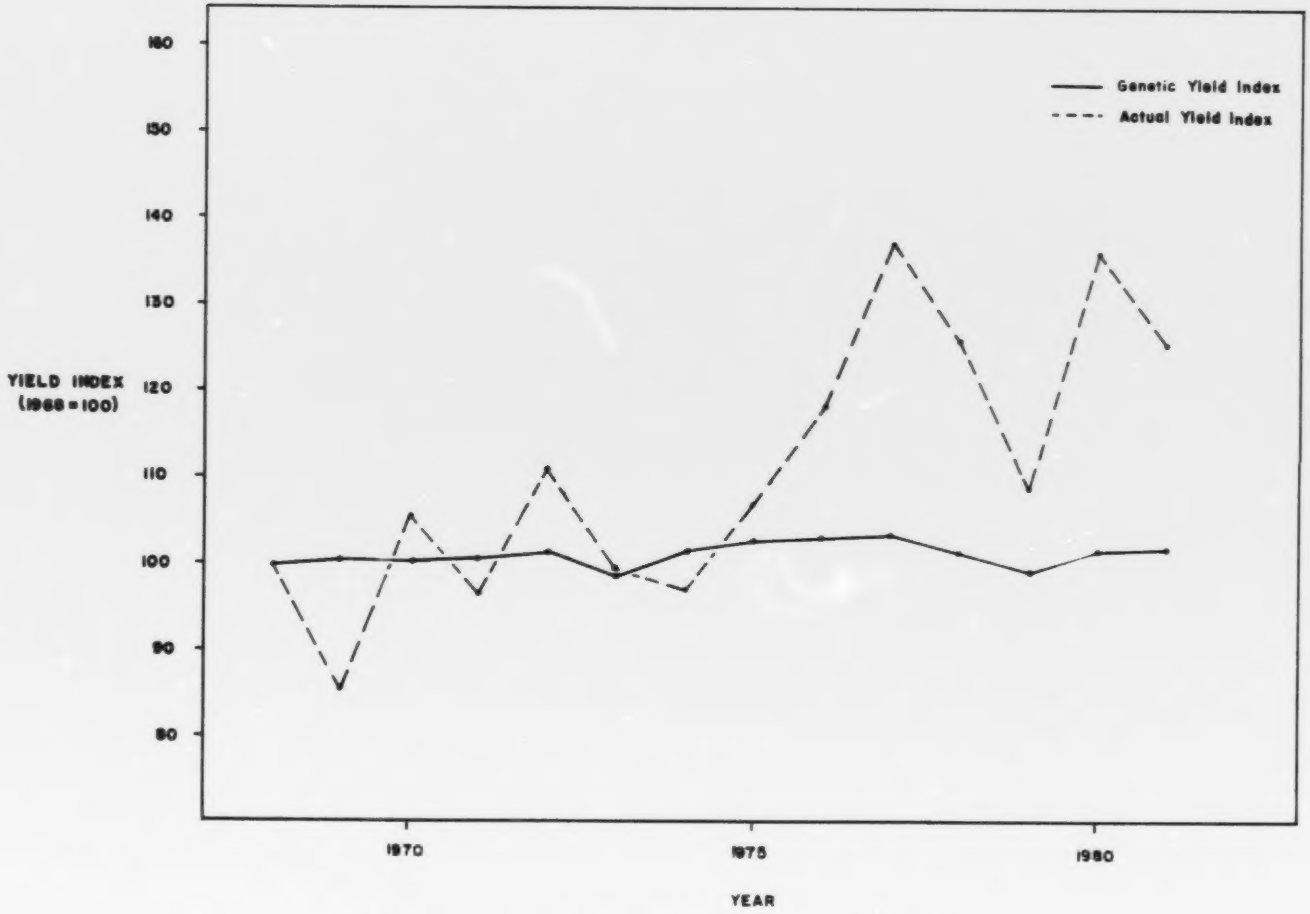

Table B.1.
NATIONAL AND INTERNATIONAL EXPENDITURES ON AGRICULTURAL RESEARCH, SELECTED YEARS

Country/Region	Expenditures							
	1959	1962	1965	1968	1971	1974	1979	1980
	($,000,000 1980 US $)							
Canada	104.7 (5.1)[a]	108.6 (3.6)	129.0 (3.2)	211.3 (4.5)	234.8 (4.2)	229.2 (3.7)	277.9 (4.1)	241.2 (3.3)
U.S.	564.2 (27.3)	648.9 (21.6)	808.4 (20.2)	939.3 (20.0)	1056.6 (19.1)	1050.7 (16.8)	1072.9 (15.8)	1094.3 (14.8)
North America & Oceania	760.5 (36.8)	870.9 (29.1)	1121.9 (28.0)	1121.9 (23.9)	1350.7 (24.4)	1619.4 (25.8)	1617.8 (23.8)	1713.1 (23.2)
Latin America	79.6 (3.9)	105.4 (3.5)	157.9 (3.9)	194.9 (4.2)	237.1 (4.3)	320.3 (5.1)	338.3 (5.0)	462.6 (6.3)
Asia	261.1 (12.7)	465.2 (15.5)	806.3 (20.1)	1062.8 (22.6)	1347.4 (24.4)	1493.8 (23.8)	1707.4 (25.2)	1797.9 (24.4)
Africa	119.1 (5.8)	168.2 (5.6)	230.3 (5.7)	244.6 (5.2)	258.5 (4.7)	264.9 (4.2)	433.3 (6.4)	424.8 (5.7)
Eastern Europe & USSR	568.3 (27.5)	939.2 (31.3)	1073.0 (26.8)	1204.2 (25.7)	1360.2 (24.6)	1505.9 (24.1)	1492.8 (22.0)	1492.8 (20.2)
Western Europe	275.0 (13.3)	448.7 (15.0)	620.6 (15.5)	865.6 (18.4)	971.7 (17.6)	1062.3 (17.0)	1195.0 (17.6)	1489.6 (20.2)
TOTAL	2063.6 (100.0)	2997.6 (100.0)	4010.0 (100.0)	4694.0 (100.0)	5525.6 (100.0)	6266.6 (100.0)	6784.6 (100.0)	7380.8 (100.0)

[a] Numbers in brackets indicate percentage breakdown.
Source: Data provided courtesy of Dr. R. Evenson, Yale University.

Table B.2
APPROXIMATE RELATIVE YIELDS OF SELECTED CROP VARIETIES [a]

Wheat		Barley		Rapeseed/Canola	
Variety	Yield as a % of Selkirk	Variety	Yield as a % of Conquest	Variety	Yield as a % of Argentine/Polish
Benito	105	Argyle	118	Altex	121
Canthatch	106	Betzes	111	Argentine	100
Canuck	105	Bonanza	117	Midas	116
Chester	105	Centennial	111	Oro	106
Chinook	97	Conquest	100	Regent	116
Columbus	112	Elrose	121	Tanka	105
Cypress	96	Fairfield	127	Target	110
Leader	110	Fergus	122	Tower	109
Manitou	106	Galt	114	Turret	113
Napayo	107	Gateway	80	Zephyr	107
Neepawa	107	Johnston	138		
Park	103	Jubillee	117	Arlo	101
Pembina	100	Klages	121	Candle	100
Rescue	98	Klondike	129	Echo	112
Selkirk	100	Melvin	127	Polar	109
Sinton	106	Palliser	106	Polish	100
Thatcher	105	Paragon	107	Torch	111

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[a] Relative yield data provided by Ken Panchuk, Saskatchewan Agriculture, Plant Industry Branch, Regina.

APPENDIX C

SUPPLEMENTARY DATA FOR ALBERTA AGRICULTURAL PRODUCTIVITY ESTIMATES

Table C.1

SUMMARY OF REAL OUTPUT & TOTAL RESOURCE USE IN ALBERTA AGRICULTURE, 1930-1980

($ Millions 1971)

Year	OUTPUT	INPUTS									
								INPUT TOTALS			
	(1)	Land (2)	Labor (3)	Machinery (4)	Fertilizer (5)	Other (6)	Public (7)	Series #1A (8)	Series #1B (9)	Series #1C (10)	Series #1D (11)
1930	431743	191059	682053	137686	10	63733		1074541	1074541	883482	883482
1931	412812	185799	852670	120887	47	60740		1220143	1220143	1034344	1034344
1932	437394	178628	981116	115781	170	56633		1332328	1332328	1153700	1153700
1933	318322	182575	1013233	113057	93	42777		1361735	1361735	1179160	1179160
1934	339C90	172673	1002848	111234	177	63382		1350314	1350314	1177641	1177641
1935	347136	165139	967320	106695	412	58732		1298298	1298298	1133159	1133159
1936	299446	160290	936566	103075	349	61469		1261769	1261769	1101479	1101479
1937	271512	154577	925460	107310	479	74956		1262782	1262782	1108205	1108205
1938	375297	143194	899337	105991	542	78603		1227667	1227667	1084473	1084473
1939	411377	153227	854402	109697	411	82333		1200070	1200070	1046843	1046843
1940	408023	145822	738163	121047	592	84625		1090249	1090249	944427	944427
1941	444695	135187	650462	127594	444	79924		993611	993611	858424	858424
1942	456191	138717	512011	136803	562	117380		905473	905473	766756	766756
1943	460517	146507	420640	142822	450	109886		820305	820305	673798	673798
1944	577765	157133	387060	149360	610	123923		818086	818086	660953	660953
1945	426657	165451	347259	167188	1072	112057		793027	793027	627576	627576
1946	372869	173686	344253	177547	1232	126753		823471	823471	649785	649785
1947	427401	182255	350500	189590	1707	137428		861480	861480	679225	679225
1948	481435	193743	352383	204060	2059	126075		878320	878320	684577	684577
1949	480239	197070	344129	210497	2928	109127		863751	863751	666681	666681
1950	370663	187155	354826	236464	3368	107131		888944	888944	701789	701789
1951	420380	180019	352704	238845	3914	110697		886179	886179	706160	706160
1952	542312	176039	305939	246746	3369	104162		836255	836255	660216	660216
1953	550542	216967	312296	262039	4005	91807		887114	887114	670147	670147
1954	464579	204528	291531	262155	3118	84039		845371	845371	640843	640843
1955	462996	196946	308160	263083	2709	99269		870167	870167	673221	673221
1956	544355	201709	313907	255611	3102	103521		878050	878050	676341	676341
1957	549631	200811	303200	249434	3884	97350		854679	854679	653868	653868
1958	602511	218147	301330	243545	4852	108177		876051	876051	657904	657904
1959	577333	221417	304470	243866	6433	113406		889592	889592	668175	668175
1960	594232	223529	300827	244573	7460	113824		890213	890213	666684	666684
1961	600575	225941	296433	241176	9343	122306		895199	895199	669258	669254
1962	587330	235889	298968	251575	11458	133270		931160	931160	695271	695271
1963	550308	239323	290000	257646	15232	139315		941516	941516	702193	702193
1964	659624	243764	286864	262520	20865	143076		957089	957089	713325	713325
1965	684359	238933	275914	271453	23178	147426	7783	964687	956904	725754	717971
1966	735097	242628	259312	283607	27804	164260	6242	983853	977611	741225	734983
1967	773167	241536	265706	299472	37675	158008	7445	1009842	1002397	768306	760861
1968	810872	239849	252887	304444	42132	153430	10717	1003459	992742	763610	752893
1969	718573	226707	265910	305479	28631	147210	19479	993416	973937	766709	747230
1970	715344	233737	257126	283707	23002	149887	25375	972834	947459	739097	713722
1971	803673	259140	251597	279742	31277	156194	30792	1008742	977950	749602	718810
1972	756495	255876	241637	302029	32103	155162	27290	1014097	986807	758221	730931
1973	632574	287787	240132	327772	41713	187456	9943	1094803	1084860	807016	797073
1974	730902	305936	237241	361141	53432	210997	14468	1183215	1168747	877279	862811
1975	859253	325116	238427	377727	62811	201597	24017	1229695	1205678	904579	880562
1976	914301	310002	270453	384168	57582	197579	42469	1262253	1219784	952251	909782
1977	989709	306195	255708	406081	53596	263404	76303	1361287	1284984	1055092	978789
1978	994031	318514	256690	426109	67242	268251	52563	1389369	1336806	1070855	1018292
1979	1044987	337402	250226	445790	77712	307148	45015	1463293	1418278	1125891	1080876
1980	1100348	339006	261674	449070	66201	314770	45643	1476364	1430721	1137358	1091715

Sources: Column (1): Table C.2
Column (2): Table C.3
Column (3): Table C.4
Columns (4), (5), (6): Table C.5
Column (7): Table C.6

Column (8): Basic data (Series #1A), with related public expenditures, (Column 7), and land degradation costs.
Column (9): Basic data (Series #1B), without related expenditures.
Column (10): Basic data (Series #1C), without land degradation costs
Column (11): Basic data (Series #1D), without land degradation costs and without public expenditures.

Table C.2

REAL OUTPUT IN ALBERTA AGRICULTURE, 1930-1980

(\$ Thousands 1971)

Year	Farm Cash Receipts			Price Index
	Crops	Livestock	TOTAL	
1930	261672	170071	431743	22.4
1931	256568	156244	412812	17.6
1932	312212	125182	437394	16.2
1933	214883	103439	318322	22.4
1934	225291	113799	339090	28.6
1935	218217	128919	347136	28.6
1936	167336	132109	299446	31.9
1937	164513	106998	271512	44.6
1938	253618	121679	375297	35.8
1939	254048	157329	411377	28.8
1940	223900	184123	408023	30.8
1941	212444	232250	444695	34.9
1942	181470	274721	456191	41.3
1943	190328	270189	460517	50.9
1944	302444	275321	577765	60.0
1945	205827	220830	426657	68.9
1946	199008	173860	372869	77.2
1947	254702	172698	427401	81.4
1948	273593	207842	481435	92.2
1949	281637	198602	480239	93.2
1950	175554	195109	370663	96.9
1951	227949	192430	420380	108.1
1952	348992	193320	542312	93.1
1953	331573	218968	550542	87.0
1954	218378	246202	464579	81.6
1955	211572	251424	462996	78.3
1956	277400	266954	544355	78.6
1957	241380	308250	549631	78.2
1958	248415	354096	602511	82.9
1959	245345	331988	577333	84.0
1960	262435	331797	594232	82.9
1961	263871	336703	600575	90.3
1962	264144	323186	587330	97.7
1963	252410	297899	550308	95.1
1964	342830	316793	659624	92.1
1965	328403	355957	684359	95.7
1966	352417	382681	735097	104.6
1967	376971	396196	773167	102.8
1968	375301	435571	810872	98.9
1969	285863	432710	718573	101.5
1970	259915	455429	715344	100.0
1971	325041	478632	803673	100.0
1972	314020	442475	756495	117.3
1973	241086	391488	632574	185.6
1974	369415	361487	730902	226.6
1975	450091	409163	859253	216.0
1976	451859	462442	914301	200.1
1977	460005	529704	989709	193.0
1978	411775	582256	994031	226.4
1979	447400	597586	1044987	270.1
1980	513355	586994	1100348	283.3

Notes:

Columns (1) - (3): Basic data in: Alberta Agriculture, *A Historical Series of Agricultural Statistics for Alberta*, Agdex #850, Edmonton, 1969; Alberta Agriculture, *op. cit.*, supplement, Edmonton, 1973; and Alberta Agriculture, *Agricultural Statistics Yearbook*, Edmonton, 1972-1980. Deflated by Column (4).

Column (4): *Western Canada Product Price Index*, Statistics Canada, Cat. #62-004. For 1930-34, the indices were estimated using wheat price fluctuations.

Table C.3

LAND & BUILDING USE IN ALBERTA AGRICULTURE, 1930-1980
(\$ Thousands 1971)

Year	Capital (1)	Land "Depreciation" (2)	Building Repairs (3)	Building Depreciation (4)	TOTAL (5)	Land Price Index (6)
1930	164433	8	6717	19901	191059	23.3
1931	159105	229	6678	19787	185799	21.0
1932	153388	604	6214	18422	178628	19.1
1933	157521	557	6182	18315	182575	18.1
1934	147948	817	6032	17876	172673	18.4
1935	140271	1148	5989	17731	165139	18.5
1936	136053	1032	5858	17347	160290	19.0
1937	130553	1248	5745	17031	154577	19.6
1938	119854	1956	5399	15985	143194	19.8
1939	127882	2044	5878	17423	153227	19.6
1940	121584	2219	5078	16941	145822	20.3
1941	113617	2102	4912	14556	135187	21.6
1942	115302	2018	5727	15670	138717	22.6
1943	120871	2031	6257	17348	146507	22.9
1944	127349	3265	7333	19186	157133	23.1
1945	133296	2773	8403	20979	165451	23.3
1946	135696	2916	12290	22784	173686	24.1
1947	142041	3869	12148	24197	182255	26.3
1948	150053	4438	13322	25930	193743	30.0
1949	151420	5673	13442	26535	197070	30.9
1950	144484	4573	13065	25033	187155	33.8
1951	138701	5596	11984	23738	180019	36.6
1952	133591	6600	12424	23424	176039	38.0
1953	166957	7035	14637	28338	216967	39.4
1954	159936	5097	12471	27024	204528	38.0
1955	154758	4811	10609	26768	196946	40.8
1956	155594	6047	12494	27574	201709	42.2
1957	155594	6291	10813	28113	200811	42.2
1958	167751	7407	11950	31039	218147	43.6
1959	168054	9022	13246	31095	221417	45.0
1960	168931	10366	12974	31258	223529	49.3
1961	169168	12041	13430	31302	225941	50.7
1962	174306	13898	15434	32251	235889	52.1
1963	176238	16851	13625	32609	239323	56.3
1964	175070	23230	13071	32393	234764	63.3
1965	171100	25039	11135	31659	238933	74.6
1966	169995	29453	11279	31901	242628	83.1
1967	162606	38235	10608	30087	241536	98.5
1968	158303	42159	10096	29291	239849	109.8
1969	157139	29615	10877	29076	226707	108.4
1970	159805	24854	16414	32664	233737	101.4
1971	176513	33505	15912	33210	259140	100.0
1972	177077	34261	15841	28697	255876	117.0
1973	200513	40747	17214	29313	287787	129.1
1974	208232	54663	17129	25912	305936	167.4
1975	219664	65651	15577	24224	325116	203.9
1976	212636	62472	13149	21745	310002	249.8
1977	218945	60543	10590	16117	306195	300.5
1978	225494	70501	8822	13697	318514	379.0
1979	232154	81392	8227	15629	337402	456.0
1980	239030	76352	7214	16410	339006	543.1

Notes:

Column (1): Estimate based on a real rate of interest of 5% per annum; a measure of the opportunity cost of capital invested in land and buildings. Basic data in; Alberta Agriculture, *A Historical Series of Agricultural Statistics for Alberta*, Agdex #850, Edmonton 1969; Alberta Agriculture, *op. cit.*, supplement, Edmonton, 1973, and Alberta Agriculture, *Agricultural Statistics Yearbook*, Edmonton, 1972-1980.
Deflated by Column (6).

Column (2): For details, see accompanying Table C.3(a) following.

Column (3) - (4): Basic data as per Column (1).
Deflated by Column (6).

Column (6): Basic data for 1972-81 from Alberta Agriculture, *Alberta Real Estate Values in 1981*, Edmonton, p.28. Data for the years 1959-1971 taken directly from: Marv Anderson & Assoc./ECA, *Factors Affecting Summerfallow Acreage in Alberta*, Edmonton, January 1980, p. 48. Data for 1949-58 is derived from comparable Saskatchewan estimates (Saskatchewan Agricultural Statistics 1981) less \$2.00/acre. Prices prior to 1949 assumed to fluctuate like the Consumer Price Index.

Table C.3 (a)

THE COST OF SOIL DEGRADATION IN ALBERTA AGRICULTURE
($ Thousands 1971)

Year	Salinity (1)	Fertility Losses (2)	Erosion (3)	TOTAL (4)
1930	-	8	0	8
1931	-	37	192	229
1932	-	136	468	604
1933	-	74	483	557
1934		141	676	817
1935		330	818	1148
1936		279	753	1032
1937		384	864	1248
1938		434	1522	1956
1939		329	1715	2044
1940	66	474	1679	2219
1941	122	355	1625	2102
1942	153	450	1415	2018
1943	157	361	1513	2031
1944	327	488	2450	3265
1945	218	857	1698	2773
1946	259	985	1672	2916
1947	326	1365	2178	3869
1948	412	1646	2380	4438
1949	417	2341	2915	5673
1950	298	2695	1580	4573
1951	380	3130	2086	5596
1952	659	2695	3246	6600
1953	698	3204	3133	7035
1954	506	2495	2096	5097
1955	582	2166	2063	4811
1956	819	2482	2746	6047
1957	759	3106	2426	6291
1958	992	3881	2534	7407
1959	968	5147	2907	9022
1960	1252	5965	3149	10366
1961	1357	7478	3206	12041
1962	1482	9167	3249	13898
1963	1526	12183	3142	16851
1964	2215	16695	4320	23230
1965	2312	18540	4187	25039
1966	2674	22233	4546	29453
1967	3183	30133	4919	38235
1968	3485	33720	4954	42159
1969	2892	22907	3816	29615
1970	2934	18411	3509	24854
1971	4046	25022	4437	33505
1972	4246	25682	4333	34261
1973	4014	33370	3363	40747
1974	6708	42746	5209	54663
1975	8988	50249	6414	65651
1976	9899	46066	6507	62472
1977	10973	42877	6693	60543
1978	10654	53794	6053	70501
1979	12578	62170	6644	81392
1980	15691	52961	7700	76352

Notes:

Column (1): Estimates are based on the following assumptions:
- dryland saline area in 1980 = 200,000 ha., increasing at 10% per year.
- salinity on irrigated lands in 1980 = 100,000 ha., also increasing at 10% per year.
- the losses are cumulative.
- revenue loss = 75% of annual average revenue/ha. for the total area in Alberta in crops and improved pasture.

For rationale underlying assumptions, see text. For the Alberta area in crops and improved pasture, see the *Agricultural Census*, various years. (Inter-census years interpolated.)

Column (2): Estimates assume an annual chemical fertilizer (or equivalent recharge) deficiency of 80%. Thus, the annual "mining" cost is calculated to be:

(cost of fertilizer) X .8

See especially, W.B. McGill/ECA, *Soil Fertility and Land Productivity in Alberta*, Edmonton, 1982, p.79. For further rationale, see text.

Column (3): Estimates are based on the following parameters:
- 5% of cropland affected during the 1930's.
- an additional 5% affected during 1940-1980.
- the losses are cumulative.
- revenue loss = 15% of annual crop revenues on affected areas.

For rationale underlying assumptions, see text. Also see: DRIE/PFRA, *Land Degradation and Soil Conservation Issues*, Regina, November 1982.

Table C.4

LABOR UTILIZATION IN ALBERTA AGRICULTURE, 1930-1980
(\$ Thousands 1971)

Year	Wages to Farm Labor (1)	Imputed Wages to Owner-Operator (2)	Imputed Wages to Family Labor (3)	TOTAL (4)	Wage Price Index (5)
1930	117289.4	463182.3	101581.1	682052.8	14.1
1931	124922.7	600755.7	126991.7	852670.1	10.1
1932	134873.2	700114.2	146128.5	981115.9	7.9
1933	144005.6	718319.5	150907.9	1013233.0	7.3
1934	147705.9	705778.8	149363.1	1002847.8	7.6
1935	153746.7	669508.0	144065.6	967320.3	8.0
1936	148266.0	648815.7	139484.6	936566.3	8.5
1937	145884.2	641744.8	137831.2	925460.2	8.9
1938	146062.4	619326.8	133947.4	899336.6	9.3
1939	142251.2	584896.4	127253.9	854401.5	9.8
1940	120387.2	507836.0	109940.1	738163.3	11.8
1941	103616.5	449968.1	96876.9	650461.5	14.1
1942	88668.2	347087.5	76254.9	512010.6	18.9
1943	80792.8	277197.7	62649.5	420640.0	23.6
1944	75942.3	253470.1	57647.1	387059.5	25.5
1945	62892.9	232646.7	51719.0	347258.6	27.6
1946	63497.5	229484.6	51271.2	344253.3	28.4
1947	67115.9	231182.8	52201.6	350500.3	30.2
1948	61960.1	237939.1	52483.6	352382.8	32.9
1949	59996.5	232879.4	51253.5	344129.4	34.0
1950	67408.1	234571.5	52846.8	354826.4	34.0
1951	67745.6	232429.0	52529.8	352704.4	37.8
1952	59555.1	200818.5	45565.7	305939.3	44.3
1953	60280.5	205504.4	46511.1	312296.0	42.4
1954	53057.5	195053.9	43419.4	291530.8	44.8
1955	62126.5	200136.7	45897.0	308160.2	40.7
1956	62413.4	204741.7	46752.3	313907.4	43.2
1957	62219.6	195823.8	45156.9	303200.3	45.9
1958	63161.9	194315.5	43852.9	301330.3	47.9
1959	63426.1	196826.7	44216.8	304469.6	49.9
1960	64684.4	192634.7	43508.0	300827.1	51.6
1961	64641.7	182678.8	49112.7	296433.2	52.7
1962	64099.1	186424.0	48444.4	298967.5	53.6
1963	64042.4	182856.6	43100.5	289999.5	55.4
1964	61417.8	182993.7	42452.9	286864.4	57.9
1965	58589.7	177045.1	40278.8	275913.6	62.6
1966	51435.9	169742.3	38134.0	259312.2	71.5
1967	51873.9	174047.0	39784.9	265705.8	77.6
1968	50469.7	164430.1	37987.2	252887.0	83.5
1969	46646.2	178755.3	40508.3	265909.8	89.9
1970	40255.7	178575.2	38294.9	257125.8	94.8
1971	39332.0	173685.0	38580.0	251597.0	100.0
1972	38027.6	166597.6	37012.0	241637.2	108.6
1973	40725.2	163062.9	36344.1	240132.2	124.1
1974	40842.2	161584.0	34815.2	237241.4	148.3
1975	40447.0	162241.1	35738.5	238426.6	176.3
1976	36562.9	193991.6	39898.2	270452.7	203.4
1977	39567.3	178811.3	37329.5	255708.1	225.8
1978	40604.4	177977.1	38108.8	256690.3	239.9
1979	41513.6	172745.4	35966.5	250225.5	254.1
1980	46842.1	176591.6	38240.5	261674.2	272.3

Notes:

Column (1): Basic data in Alberta Agriculture, *A Historical Series of Agricultural Statistics for Alberta*, Agdex #850, Edmonton, 1969; Alberta Agriculture, *op. cit.*, supplement, Edmonton, 1972; and Alberta Agriculture, *Agriculture Statistics Year-book*, Edmonton, 1972-80. Deflated by Column (5).

Column (2): Estimated as follows:
(No. of farm operators) X (Annual average wage for hired labor, with board)
Wage rate for 1953-1975 taken from Statistics Canada, *Quarterly Bulletin of Agricultural Statistics*, Catalogue #21-003, Ottawa, January-March 1975. (National Estimates). Estimates for 1976-80 obtained from *monthly* wage rate estimates, same publication. Estimates for 1930-1952 obtained by indexing the 1953 rate to the CPI, 1930-1953. Deflated by Column (5).

Column (3): Calculated by assuming that the relative importance of family labor in Canadian agriculture was also typical of Alberta. Employment estimates for 1958-1980 taken directly from: Statistics Canada, *The Labor Force*, Catalogue No. 71-001, Ottawa, various issues. During 1930-57, it was simply assumed that the unpaid farm family labor force remained at a constant 20% of total employment in agriculture.
It was further assumed that the imputed wage rate for unpaid family workers was equal to 70% of the rate for owner-operators.
Subsequently deflated by Column (5).

Column (5): Western Canada Farm Wage Index. See: Statistics Canada, *Price Index Numbers of Commodities and Services used by Farmers*, Catalogue #62-004, Ottawa, various years.

General Note: The basic methodology employed is generally consistent with B.E. Prentice and G.L. Brinkman, *The Value of Agricultural Research in Ontario*, OAC/University of Guelph, July 1982. The use of value estimates herein eliminates the need to adjust the employment estimates for qualitative changes (re: education) and lifestyle changes over time (re: hours employed).

Table C.5

MACHINERY, FERTILIZER & OTHER INPUT USE IN ALBERTA AGRICULTURE, 1930-1980

($ Thousands, 1971)

Year	MACHINERY				FERTILIZER	OTHER	PRICE INDEX		
	Cash Costs	Depreciation	Capital	TOTAL			Machinery	Fertilizer	Other
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1930	62254	54664	20768	137686	10	63733	28.0	61.9	28.2
1931	52974	46690	21223	120887	47	60740	27.4	58.0	24.6
1932	50636	43776	21379	115781	170	56633	27.2	50.7	23.3
1933	48929	42267	21861	113057	93	52777	26.6	51.8	22.2
1934	51387	38624	21223	111234	177	63382	27.4	53.3	23.1
1935	53120	36833	16742	106695	412	58732	27.5	52.4	23.2
1936	52053	35078	15944	103075	349	61489	28.2	54.2	23.5
1937	55150	35861	16300	107310	479	74956	28.0	54.2	24.6
1938	54201	35605	16185	105991	542	78603	29.9	55.3	24.3
1939	59862	34262	15573	109697	411	82333	29.8	54.9	23.8
1940	63803	39355	17889	121047	592	84625	30.4	54.9	25.3
1941	68420	40682	18492	127594	444	79924	31.4	56.1	26.8
1942	75729	41988	19086	136803	562	117380	32.9	56.2	29.9
1943	78899	43947	19976	142822	450	109886	33.8	55.7	31.6
1944	84321	44714	20324	149360	610	123923	34.3	55.7	33.0
1945	94702	49834	22652	167188	1072	112057	33.2	55.7	33.5
1946	101367	52373	23806	177547	1232	126753	34.3	55.7	34.7
1947	106234	57308	26048	189590	1707	137428	36.4	56.8	39.4
1948	114736	61411	27913	204060	2059	126075	40.9	62.9	45.4
1949	112921	67083	30493	210497	2928	109127	45.7	68.1	47.6
1950	123857	77417	35189	236464	3368	107131	47.7	71.5	49.4
1951	123287	79446	36111	238845	3914	110697	54.0	83.6	53.8
1952	127855	81823	37068	246746	3369	104162	56.5	88.8	56.5
1953	132356	89361	40321	262039	4005	91807	57.0	90.2	56.7
1954	126721	93430	42003	262155	3118	84039	57.4	96.2	56.3
1955	132217	90384	40482	263083	2709	99269	57.6	92.5	56.0
1956	133192	84737	37882	255811	3102	103521	60.5	91.9	58.1
1957	128944	83261	37229	249434	3884	97350	64.4	91.4	59.9
1958	124982	81959	36604	243545	4852	108177	68.0	94.1	61.5
1959	125721	81681	36464	243866	6433	113406	71.2	95.0	63.5
1960	123591	83701	37281	244573	7460	113824	72.9	93.1	65.1
1961	121665	82737	36774	241176	9343	122306	74.9	90.8	66.3
1962	127302	87113	37160	251575	11458	133270	77.1	92.4	68.1
1963	130106	89328	38212	257646	15232	139315	78.4	94.0	69.5
1964	131413	91868	39239	262520	20865	143076	80.4	97.0	72.3
1965	135498	95079	40876	271453	23178	147426	81.9	97.9	75.1
1966	135545	105418	42644	283607	27804	164260	84.6	95.6	79.2
1967	137609	113450	48413	299472	37675	158008	87.1	96.5	84.1
1968	136173	118602	49669	304444	42132	153430	90.8	97.9	89.3
1969	135887	119847	49745	305479	28631	147210	93.9	97.5	93.8
1970	140749	93579	49379	283707	23002	149887	96.9	98.7	96.9
1971	146513	89857	43372	279742	31277	156194	100.0	100.0	100.0
1972	154130	104264	43634	302029	32103	155162	103.8	109.8	106.8
1973	175368	107023	45381	327772	41713	187456	108.7	110.7	124.4
1974	193783	115069	52289	361141	53432	210997	122.0	133.0	144.3
1975	192342	124625	60760	377727	62811	201597	142.1	180.8	163.0
1976	189770	127624	66774	384168	57582	197579	158.0	212.6	174.9
1977	162965	173366	69751	406081	53596	263404	170.2	214.0	179.5
1978	165156	186137	74817	426109	67242	268251	178.7	211.7	203.0
1979	170586	195053	80151	445790	77712	307148	192.9	230.6	237.3
1980	176724	193040	79306	449070	66201	314770	223.4	306.5	260.4

Notes:

Column (1): Includes petroleum, diesel oil, lubricants, machinery repairs, tires, licenses, and insurance. Basic data in: Alberta Agriculture, *A Historical Series of Agricultural Statistics for Alberta*, Agdex #850, Edmonton, 1969; Alberta Agriculture, *op. cit.*, supplement, 1972; and Alberta Agriculture, *Agricultural Statistics Yearbook*, Edmonton, 1972-1980.
Deflated by Column (7).

Column (2): Basic sources as per Column (1).
Also deflated by Column (7).

Column (3): An estimate of the opportunity cost of capital in machinery and equipment. Assumes that the real rate of interest applicable is 5 percent annum. (Also see Table C.3) Basic sources as per Column (1).
Also deflated by Column (7).

Column (4): Summation of Columns (1) through (3).

Column (5): Basic sources as per Column (1).
Deflated by Column (8).

Column (6): Includes "other crop expenses" (pesticides, nursery stock, irrigation, containers, seed and twine), commercial feed purchases, other livestock expenses (purchases, A.I., purebred registration fees, and veterinary expenses), electricity and telephone, and miscellaneous. Basic sources as per Column (1).
Deflated by Column (9).

Column (7): Western Canada Farm Machinery Price Index. See Statistics Canada, *Index Numbers of Commodities and Services Used by Farmers*, Catalogue #62-004, Ottawa, various years.

Column (8): Western Canada Fertilizer Price Index. For basic source, see Column (7).

Column (9): Western Canada Composite Input Price Index. For basic source, see Column (7).

Table C.6

PUBLIC TRANSFER PAYMENTS IN ALBERTA AGRICULTURE, 1930-1980
($ '000 1971)

Year	AMOUNT PAID			AMOUNT RECEIVED				CPI Price Index
	Property Taxes	Income Taxes	TOTAL	R & D	Direct Payments	TOTAL	DIFFERENCE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1930	17676	-	-	-	-	-	-	43.6
1931	18108	-	-	-	-	-	-	39.4
1932	18335	-	-	-	-	-	-	35.8
1933	18097	-	-	-	-	-	-	33.9
1934	17610	-	-	-	-	-	-	34.5
1935	17549	-	-	-	-	-	-	34.7
1936	17055	-	-	-	-	-	-	35.6
1937	16865	-	-	-	-	-	-	36.6
1938	17605	-	-	-	-	-	-	37.1
1939	17509	-	-	-	-	-	-	36.6
1940	16911	-	-	-	-	-	-	38.1
1941	16699	-	-	-	-	-	-	40.4
1942	16122	-	-	-	-	-	-	42.3
1943	16222	-	-	-	-	-	-	42.9
1944	16850	-	-	-	-	-	-	43.2
1945	18461	-	-	-	-	-	-	43.6
1946	21313	-	-	-	-	-	-	45.1
1947	21860	-	-	-	-	-	-	49.3
1948	22345	-	-	-	-	-	-	56.2
1949	24524	-	-	-	-	-	-	57.9
1950	24878	n.a.	24878	n.a.	-	-	-	59.6
1951	22780	n.a.	22780	6503	-	-	-	65.9
1952	23630	12356	35986	6813	-	-	-	67.6
1953	25335	9779	35114	8522	-	-	-	66.9
1954	25945	3506	29451	11419	-	-	-	67.4
1955	25083	3972	29055	14673	-	-	-	67.4
1956	25673	5948	31621	18268	-	-	-	68.4
1957	24922	6535	31457	21457	-	-	-	70.7
1958	24572	8550	33122	22118	-	-	-	72.6
1959	25120	9230	34350	23760	-	-	-	73.3
1960	26457	8640	35097	24886	-	-	-	74.3
1961	27353	9645	36998	26839	-	-	-	74.9
1962	27576	10843	38419	28096	-	-	-	75.8
1963	27698	10063	37761	30025	-	-	-	77.3
1964	27889	13715	41604	33073	-	n.a.	-	78.5
1965	27978	15875	43853	28479	23157	51636	7783	80.4
1966	30952	19036	49988	27514	28716	56230	6242	83.4
1967	32226	22442	54668	28301	33812	62113	7445	86.5
1968	34077	22563	56640	28898	38459	67357	10717	89.9
1969	34341	16843	51184	28275	42388	70663	19479	94.1
1970	32695	16049	48744	27541	50886	74119	25375	97.1
1971	32270	19086	51356	31262	50886	82148	30792	100.0
1972	32134	25291	57425	29597	55118	84715	27290	104.8
1973	30809	46226	77035	31091	55887	86978	9943	112.6
1974	28887	71970	100857	30321	85004	115325	14468	125.1
1975	31881	66092	99973	30639	93351	123990	24017	138.5
1976	33960	47202	81162	30295	93336	123631	42469	148.8
1977	17653	35837	53490	31829	97964	129793	76303	160.8
1978	17757	34066	51823	33357	71029	104386	52563	175.2
1979	16274	44088	60362	34348	71029	105377	45105	191.2
1980	16677	44088	60765	35379	71029	106408	45643	210.5

Notes:

Column (1): Basic data in: Alberta Agriculture, *A Historical Series of Agricultural Statistics for Alberta*, Agdex #850, Edmonton, 1969; Alberta Agriculture, *op. cit.*, supplement, Edmonton, 1973; and Alberta Agriculture, *Agricultural Statistics Yearbook*, Edmonton, 1972-1980. Deflated by Column (8).

Column (2): Basic data from: Revenue Canada, *Taxation Statistics*, Ottawa, annual issues. Deflated by Column (8).

Column (4): Agricultural research expenditures for Alberta (provincial and total federal), lagged six years. E.g. 1951 = actual expenditures in 1944-45. Deflated by Column (8).

Column (5): Direct payments plus subsidies. Canadian estimates tabulated in: G.L. Brinkman, *Farm Incomes in Canada*, ECC, Ottawa, 1981, p.54. Alberta farmers assumed to receive their share according to relative farm numbers, i.e. approximately 15 percent of the total. Deflated by Column (8).

Column (7): Column (6) minus Column (3). The difference is assumed to equal zero prior to 1965.

APPENDIX D

SUPPLEMENTARY DATA FOR ALBERTA AGRICULTURAL PRODUCTIVITY PROJECTIONS

Table D.1
REAL INPUT PRICE PROJECTIONS, 1980-2030 [a]
(1980=100)

Year	Fuel	Fertilizer	Chemicals	Machinery
		PESSIMISTIC SCENARIO		
1980	100	100	100	100
1990	175	125	100	104
2000	250	150	100	108
2010	325	175	100	112
2020	400	200	100	116
2030	475	225	100	125
		OPTIMISTIC SCENARIO		
1980	100	100	100	100
1990	155	120	100	103
2000	210	140	100	106
2010	265	160	100	109
2020	320	180	100	112
2030	375	200	100	115

[a] Purchased inputs.

Table D.2

SUMMARY PROJECTIONS OF AGRICULTURAL LAND USE ALBERTA 1981-2030[a] (million acres)

Year	Total Improved Land	Crop Land	Improved Pasture	Summerfallow	Other
			PESSIMISTIC SCENARIO		
1981(actual)	31.0	20.9	3.9	5.4	0.7
1990	32.6	22.4	4.0	5.0	1.2
2000	34.2	23.7	4.3	4.6	1.6
2010	35.8	25.0	4.6	4.2	2.0
2020	37.4	26.3	4.9	3.8	2.4
2030	39.0	27.6	5.2	3.4	2.8
			OPTIMISTIC SCENARIO		
1981(actual)	31.0	20.9	3.9	5.4	0.7
1990	34.0	24.0	4.2	4.9	0.9
2000	37.4	27.0	4.6	4.4	1.4
2010	40.8	30.0	5.0	3.9	1.9
2020	44.2	33.0	5.4	3.4	2.4
2030	47.6[b]	36.0	5.8	2.9	2.9

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[a] Excludes unimproved agricultural land and ignores a possible expansion in the total agricultural land base, e.g. frontier areas. See especially: H. Horner, **A Review of the Livestock Industry in Alberta,** Dept. of Economic Development, Edmonton, 1981.

[b] Suggested limit. See Figure 6.3.

Table D.3

PHYSICAL INPUT PROJECTIONS, 1980-2030

(1980=100)

Year	Fuel	Fertilizer	Chemicals/Machinery
		PESSIMISTIC SCENARIO	
1980	100	100	100
1990	104	132	106
2000	102	167	112
2010	100	206	118
2020	98	248	123
2030	96	292	128
		OPTIMISTIC SCENARIO	
1980	100	100	100
1990	107	140	113
2000	113	183	126
2010	118	227	139
2020	122	283	152
2030	125	339	165

Table D.4

SCENARIO A: SUMMARY OF INPUT-OUTPUT PROJECTIONS[a] (1980=100)

Year	Output		Land		Labor	Machinery		Fertilizer		Other	Public
	Series #1	Series #2	Series #1	Series #2		Series #1	Series #2	Series #1	Series #2		
1980(actual)	100	100	100	100	100	100	100	100	100	100	100
1990	124	139	118	124	100	104	103	165	198	105	100
2000	152	189	137	150	100	108	106	251	351	100	100
2010	186	253	159	183	100	112	109	361	578	116	100
2020	225	330	191	224	100	116	112	496	893	122	100
2030	271	423	239	279	100	120	115	657	1314	128	100

[a] Status quo.

Table D.5

SCENARIO B: SUMMARY OF INPUT-OUTPUT PROJECTIONS[a]

(1980=100)

Year	Output		Land		Labor	Machinery		Fertilizer		Other	Public
	Series #1	Series #2	Series #1	Series #2		Series #1	Series #2	Series #1	Series #2		
1980	100	100	100	100	100	100	100	100	100	100	100
1990	124	139	118	124	100	104	103	165	198	105	172
2000	155	194	137	150	100	108	106	251	351	110	172
2010	195	264	159	183	100	112	109	361	578	116	172
2020	242	354	191	224	100	116	112	496	893	122	172
2030	299	467	239	279	100	120	115	657	1314	128	172

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[a] Accelerated research expenditures/yields.

Table D.6
SCENARIO C: SUMMARY OF INPUT-OUTPUT PROJECTIONS [a]
(1980=100)

Year	Output Series #1	Output Series #2	Land Series #1	Land Series #2	Labor	Machinery Series #1	Machinery Series #2	Fertilizer Series #1	Fertilizer Series #2	Other	Public
1980(actual)	100	100	100	100	100	100	100	100	100	100	100
1990	124	139	116	121	100	104	103	165	198	105	152
2000	152	189	128	141	100	108	106	251	351	110	152
2010	186	253	140	160	100	112	109	361	578	116	152
2020	225	330	148	172	100	116	112	496	893	122	152
2030	271	423	153	171	100	120	115	657	1314	128	152

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[a] Accelerated soil/water conservation expenditures plus decreased area subject to soil degradation.

Table D.7
SCENARIO D: SUMMARY OF INPUT-OUTPUT PROJECTIONS [a]
(1980=100)

Year	Output		Land		Labor	Machinery		Fertilizer		Other	Public
	Series #1	Series #2	Series #1	Series #2		Series #1	Series #2	Series #1	Series #2		
1980(actual)	100	100	100	100	100	100	100	100	100	100	100
1990	124	139	116	121	100	104	103	165	198	105	224
2000	155	194	129	141	100	108	106	251	351	110	224
2010	195	264	141	161	100	112	109	361	578	116	224
2020	242	354	151	176	100	116	112	496	893	122	224
2030	299	467	158	179	100	120	115	657	1214	128	224

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[a] Accelerated research expenditures **and** accelerated soil-water conservation programs (Scenerio B + Scenerio C).